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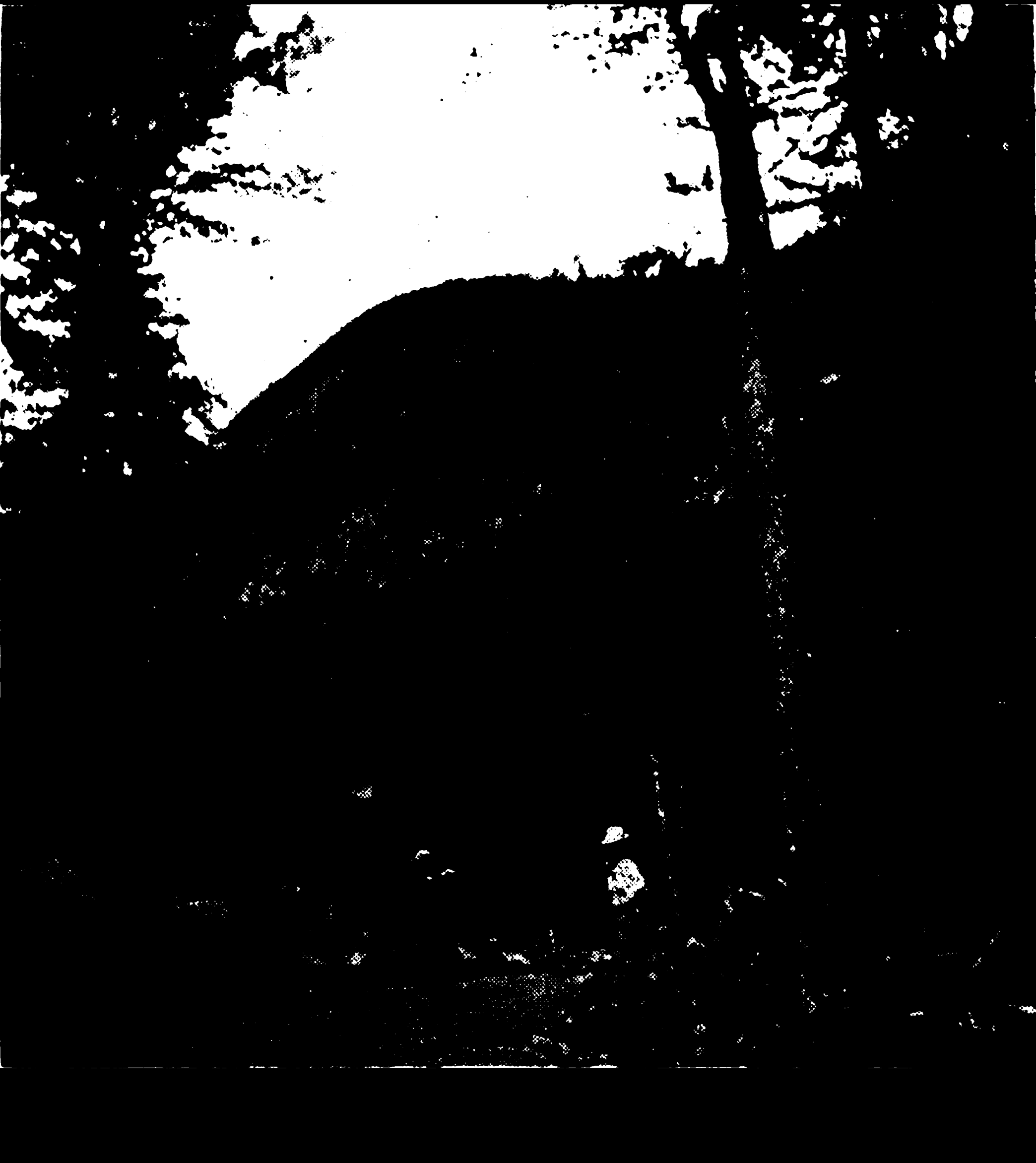

Report of the State Geologist

University of the State of New York

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University of the State of New York

New York State Museum

FREDERICK J. H. MERRILL *Director*

20th REPORT OF THE STATE GEOLOGIST

1900

Reprinted from the 54th annual report of the New York state museum

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ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1902

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20th REPORT OF THE STATE GEOLOGIST 1900

To the Regents of the University of the State of New York

I have the honor to submit herewith the report of the state geologist for the fiscal year ending Sep. 30, 1900.

In order to permit the wide distribution of separate papers, the report is, as it was last year, chiefly administrative. The larger papers giving the results of completed investigations are issued as bulletins of the state museum.

Respectfully yours

FREDERICK J. H. MERRILL

GEOLOGY

Owing to the liberal aid received from the legislature of 1899 and 1900, the director and state geologist is enabled to report a very satisfactory degree of progress in the work under his supervision.

In the field of geology the following is a synopsis of the results accomplished.

PRE-CAMBRIAN AND CRYSTALLINE ROCKS

The resurvey of Westchester county, begun some years ago by the present state geologist and since continued under his direction, has been carried nearly to completion by Edwin C. Eckel, assistant in geology, and Harry C. Magnus, volunteer assistant.

During the month of October Mr Eckel was engaged in areal work in Westchester county, covering the region near the Croton river. Records of borings for dam sites along the Croton river were obtained from Alphonse Fteley, chief engineer of the Croton aqueduct, and the materials shown by these borings were referred, so far as possible, to their respective geologic formations.

From Nov. 1 to Jan. 15 he was employed on field and office work in the final revision of the geology of the Harlem quadrangle for the New York folio. In order to use all new information rendered available by recent excavations, a number of boundaries were retraced, and careful search was made for records of borings on and near New York island. As several Jersey City records mentioned the occurrence of "gneiss," several days were spent searching for outcrops in Jersey City and in mapping the serpentine area at Hoboken.

His time from March 8 to April 8 was occupied with the final drafting of the geology of the Harlem quadrangle. During the remainder of April and all of May he was engaged in detailed work on the Carmel quadrangle and in reconnaissance work in Fairfield county, Ct. This work proved that the two bands of Harrison diorite shown in Westchester county on the map of 1895 unite in Connecticut and cover a large area.

Early in June in response to a request from Dr Macy, superintendent of the Willard state hospital, for information concerning reliable sources of water supply for that institution, he spent several days in Seneca county, investigating this question. A second visit in regard to the same matter was made in August.

The latter part of June and all of July were spent in reconnaissance in Putnam county and detailed work in northern Westchester.

Mr Eckel worked from Aug. 27 to Sep. 15 in Dutchess county, mapping, on the newly issued Millbrook quadrangle, the pre-Cambrian boundaries of Stissing and Dover mountains. A few days late in September were spent in Orange county, mapping the geologic boundaries which occur on the Schunemunk quadrangle.

Mr H. C. Magnus commenced work in Westchester county June 16 and continued till September. During this period he mapped very satisfactorily a large part of the area covered by the Tarrytown quadrangle, also spending some time on the West Point and Stamford quadrangles.

The resurvey of Putnam county, begun last year by Dr D. H. Newland, was continued by Mr Benjamin F. Hill, fellow in Columbia university. A large amount of territory was covered in reconnaissance and an extensive suite of specimens collected.

The survey of the crystalline area of the northeastern Adirondacks, begun by Prof. H. P. Cushing in 1893, has been continued by him during the past season.

The first two weeks of his field work were spent in Ontario, where, through the kindness of Dr Dawson, the director of the Canadian survey, and of Dr Barlow, he had the privilege of accompanying the latter through a most interesting region. The purpose of the trip was to make a comparison between the rocks of eastern Canada and those of the Adirondack region. While the region visited was somewhat too far to the west to afford the best possible basis for comparison, yet this drawback was more than compensated for in the very great interest of its rocks.

The Grenville series was seen to consist of rocks in every way like those comprising the crystalline limestone series of the Adirondacks. It seems also quite certain that the two series may be directly followed from one district to the other through the Thousand Island region, and it would appear quite proper that the same name should be applied to the series in both districts. It was also made apparent that the great mass of the gneisses of the Adirondacks would be classed with the Ottawa gneiss by the Canadian geologists, were the Adirondack region a part of Canada. But, on the other hand, it was manifest that other rocks were also included here which do not appear in the Adirondacks at all, and the propriety of using this name in the Adirondacks is perhaps not so evident as in the case of the Grenville rocks.

Field work in the Adirondacks was sadly hindered by the almost incessant rainfall during July and August. The work was confined to the vicinity of Tupper lake, its purpose being to determine the limit of the Tupper lake augite syenite on the west, and to determine, if possible, the relations of the syenite to the anorthosite on the one hand, and to the surrounding gneisses on the other. These relations are exceedingly obscure and puzzling, and exposures which would aid in deciphering them were not forthcoming. At one locality unmistakable anorthosite was found, cut by what was taken to be augite syenite. The intrusive is not typical and can not be traced to connection with any body of syenite, yet is still regarded as being of that rock. The syenite was found to run well to the west in St Lawrence county, and is well exposed in the many cuts along the New York Central and Hudson River railroad between Tupper lake and Horseshoe. Except on the east, where it is in contact with anorthosite, the syenite is surrounded by a belt of granitic gneiss and amphibolite, and the two are so blended and intermingled that no sharp boundary can be drawn between them. Moreover, patches of the one are found in the other, and vice versa. The relations are such that the two would naturally be classed together as parts of the same great series of gneisses. The workers in the Adirondacks have found these syenite gneisses to be very widespread, extending far beyond the limits of the anorthosites, and it is an important question to determine their exact age and relations.

At the close of the season the pre-Cambrian outcrops at Little Falls and at the "Noses" in the Mohawk valley were visited to form a comparison with those visited farther north. The rock at Little Falls belongs to the augite syenites instead of to the gabbros. It is involved with granitic and gabbroic gneisses which clearly are closely related to it and of about the same age. The rock at the "Noses" is a quartzose gneiss whose relationships are quite clearly with the crystalline limestone series, though no other rocks of that series were noted.

A visit was also made to Clinton to see Prof. Smyth's collections from the western Adirondacks and for a comparison of results and conclusions. As the work of the two observers had been wholly independent, the harmony in conclusions which the conference developed was most gratifying.

Prof. J. F. Kemp, assisted by George I. Finlay, has continued his studies of the crystalline rocks north of the Mohawk valley. Five weeks were spent by Mr Finlay, beginning July 3, in detailed mapping of the limestone areas which occur in the town of Minerva, Essex co. and in obtaining evidence as to the relation between the surrounding gneisses and anorthosites. The first two weeks was spent around Olmstedville. A third week was spent on the limestone area along the Hudson river northward from the town of North River for three miles. The remaining two weeks were occupied in tracing the limestones along the Boreas river for two miles north of its junction with the Hudson and in defining the similar area in the district between Mink pond and the Boreas.

A visit was also made to the Chain lakes on the line between Essex county and Hamilton county, where cliffs of limestone entirely similar in character to those in the town of Minerva are exposed along the north shore. The ledges of limestone which occur along the Hudson river between Blue Ledge and the mouth of Cedar river were also mapped. The theory that the limestones are in the same series of altered sediments with the heavy bedded gneisses which occur throughout the greater part of the town, receives support from the obtainable facts of stratigraphy. As far as could be ascertained, the limestones lie, very generally, closely parallel with the gneisses, and in some cases the two lie together in apparent conformity.

QUATERNARY FORMATIONS

The study of the Pleistocene deposits of the eastern part of the state was assigned to Mr J. B. Woodworth of Harvard university, a specialist of high reputation in glacial geology, who has made a detailed survey of western Long Island and a reconnaissance of the Hudson river valley through Lake Champlain to Montreal in order to consider the evidences of marine subsidence.

The month of June was spent in making a detailed map of the Oyster Bay and the Hempstead quadrangles on Long Island. This work showed the existence of an early Pleistocene series of gravels and sands, locally folded and involved with disturbed beds of underlying Cretaceous. This Pleistocene formation is thought to be the equivalent in age of McGee's Columbia formation. Resting on it are the morainal deposits of the last or Wisconsin ice epoch with an outwash plain covering the southern half of the island, except for a ridge of nonglacial gravels reaching the sea at Far Rockaway. North of the main morainal ridge is a line of sand plains with attendant morainal deposits skirting the shore. A water level 80 feet above the present sea level is marked in this stage by a well defined delta at Port Washington. In a reconnaissance of the area to the west, another level was determined at about 40 feet. The relation of the 80 foot terrace to contemporaneous sea level has not yet been determined, but the 40 foot level appears to be associated with numerous evidences of submergence to that extent early in the period of ice retreat. A detailed report on this work is contained in bulletin 48.

Subsequent work in determining the limits of the terminal moraines on eastern Long Island was done by Mr J. E. Woodman under the direction of Mr Woodworth.

A reconnaissance of the valleys of the Hudson river and Lake Champlain, occupying most of the months of July, August and September, was undertaken with the purpose of determining the nature and extent of the evidence of marine transgression clearly marked in the latter valley. Beginning on the south, the Hudson valley exhibits several series of glacial deposits corresponding to as many temporary halts in the retreating ice front. These deposits are successively newer as one proceeds northward, and each stage is accompanied by terraces bordering the present river channel. These terraces lie on an older rock terrace whose levels have been approximately determined between New York and Albany. A deeply eroded series of glacial clays was traced to within a few miles of Peekskill. Between Croton point and Haverstraw there extends the trace of a moraine with an attendant frontal plain or delta, best marked at the mouth of Croton river. At Peekskill deltas and terraces occur at an elevation of from 100 to 120 feet, the deposit at Jones Point having apparently been laid down in contact with ice in the Hudson channel.

Another terrace of this nature occurs at West Point at an elevation of 180 feet. North of the Highlands, clays reappear, capped at Newburg by glacial outwash contemporaneous with kames, indicating the presence of masses of ice just west of that city. From the mouth of Wappinger creek and thence north of Poughkeepsie the Hudson valley is again free of clays and contains deposits of gravel and sand, showing the occupation of the valley by ice remnants. Near Coxsackie the clays reappear and continue northward to and beyond Albany, forming a part of the delta of the Mohawk.

East of Albany and Troy there is a possible shore line at about 380 feet. The full interpretation of this apparent water level depends on work yet to be carried on in the Champlain valley.

A reconnaissance of the country within a radius of 10 to 15 miles of Fort Edward revealed a variety of glacial deposits, most of which are contemporaneous with masses of land ice. No definite shore lines were discovered.

The clays of the upper Hudson valley were traced as eroded remnants of a once thicker formation from Fort Ann through Comstock to Whitehall, thus connecting the upper Hudson deposits with those of Lake Champlain.

In the Lake Champlain area definite beaches were determined near Port Kent at elevations as high as 590 feet, according to the contour map. The tracing of these lines was not completed when Mr Woodworth was obliged to leave the field.

A visit was made to Mount Royal in Montreal with the result of reaching an essential agreement with the opinion of Baron De Geer that the sea stood in Pleistocene time as high as 620 feet on the sides of that mountain.

In conclusion the results of the field work for the season just past afford no decisive evidence of submergence in the lower Hudson valley, but make it probable that there was water at sea level in the upper Hudson connected with the Champlain area. It remains to determine by future special work the marine origin of the highest beaches in the Champlain area and the southward limit of these traces in the upper Hudson valley. This work may modify the general conclusions here set forth. In the report which Mr Woodworth is now preparing will be given the description of the phenomena as they were observed.

Prof. H. L. Fairchild of the University of Rochester has continued under the auspices of the state the studies of the lake basins and valleys of central New York which he began some years ago, and will soon prepare for publication a valuable report on this important subject.

In the work of the past season the larger part of July and August were spent by him in the field, with short trips during the subsequent months. The work was spread over central-western New York, but was mainly done in three districts. 1) The district east of Syracuse, or between Syracuse and Oneida; the phenomena being the remarkable series of channels cut by the glacial waters escaping toward the Mohawk. 2) The district southwest of Buffalo, or the Cattaraugus-Chautauqua region; the work being the examination of the divide with reference to the escape of the higher glacial waters, and of channels and shore lines on the slope facing the Erie basin. 3) The region of the matured shore line of Lake Iroquois between Richland and Watertown. To the first district three trips were made; to the second district, two trips; and to the third district, one trip.

The work was not completed in either the east or west districts, as unexpected and important phenomena were discovered. Final work on the Morrisville quadrangle was deferred in order to wait for the engraved map, the photolithograph being unsatisfactory. A large body of new and interesting facts has been noted and mapped, and one or two more seasons of field work will put the results in good shape for publication.

ECONOMIC GEOLOGY

Dr Heinrich Ries of Cornell university has completed an important report on the lime and cement industries of the state, which is now in the printer's hands. The report on clay industries of New York by the same author is printed and nearly ready for distribution.

Mr A. L. Parsons has studied the recent developments in the production of gypsum.

H. T. Dickinson, during the past season, has spent four months in the field study of the deposits and quarries of bluestone and flagstone in New York. An article on quarries of southeastern New York has been prepared by Mr E. C. Eckel. This work is part of that which has been initiated for the preparation of a new publication on the building stones of New York.

Tests of road metal

By arrangement made with William H. Burr C. E., professor of civil engineering in Columbia university, a number of specimens of rock used in various parts of the state for road metal were tested in the engineering laboratory at Columbia university. The method of testing was, in general, that described in museum bulletin no. 17, entitled *Road materials and road building in New York*, and the results are given in the following tables.

The tests were conducted under the direction of Prof. Burr by Prof. A. Black, his assistant.

Report of abrasion tests

Test no.	Sample	ABRASION		Remarks
		Coefficient	Percent	
1	Conklin & Foss, Rockland Lake	16.81	2.38	diabase (trap)
2	“ “	14.9	2.68	“
3	J. S. Lane & Son, Weehawken N. J.	14.39	2.78	“
4	F. E. Conley, B, Munnsville	9.08	4.4	limestone
5	F. E. Conley, A, Higginsville	8.09	4.94	sandstone
6	“ “	9.08	4.4	“
7	A. L. Swett iron works, Medina	9.64	4.15	“
8	“ “	9.08	4.4	“
9	Whitmore, Rauber & Vicinus, Rochester	13.44	2.98	limestone
10	“ “	11.84	3.38	“
11	Isaac Wagar, Saratoga Springs	9.38	4.26	“
12	“ “	9.97	4.01	“
13	Helderberg cement co. Howe Cave	6.32	6.32	“
14	“ “	6.41	6.24	“
15	Tomkins Cove stone co. Tomkins Cove	5.42	7.37	“
16	“ “	4.91	8.11	“
17	Barber asphalt paving co. Buffalo	8.68	4.6	“
18	“ “	8.82	4.53	“
19	Brown & Fleming, Verplanck	7.04	5.68	“
20	“ “	6.22	6.33	“
21	Buffalo cement co. limited, Buffalo	9.67	4.13	“
22	“ “	8.38	4.78	“
23	C. Worlock, Perryville	6.78	5.89	“
24	“ “	6.97	5.74	“
25	C. B. Whitmore, Lockport	11.43	3.5	sandstone
26	“ “	11.58	3.46	“
27	W. T. Smith, Sharon Springs	7.18	5.58	limestone
28	“ “	7.41	5.4	“
29	The Carpenter Bros. Co. Guttenberg N. J.	15.99	2.56	diabase (trap)
30	“ “	14.55	2.75	“
31	Newark lime and cement co. Rondout	9.21	4.34	limestone
32	Mohawk Valley stone co. Palatine Bridge	9.13	4.38	“
33	Dwight Babcock, Waterloo	8.2	4.88	“
34	“ “	7.98	5.01	“
35	F. E. Conley, C, Oriskany Falls	10.22	3.91	“
36	“ “	10.3	3.88	“
37	R. Dunlop & Co. Jamesville	7.77	5.15	“
38	“ “	7.63	5.24	“
39	Callanan road impt. co. South Bethlehem	9.22	4.34	“
40	“ “	9.12	4.39	“
41	Chazy marble lime co. Chazy	7.8	5.13	“
42	“ “	8.01	5	“
43	Round Island granite (Daniel E. Donovan, New York)	12.51	3.2	granite
44	A. Shear & Co. Schenectady	9.04	4.43	sandstone
45	Hudson Riv. stone sup. co. New Hamburg	13.01	3.17	limestone
46	“ “	13.35	3	“

Report of impact tests

Test no.	Sample	No. of blows
1 & 2	Conklin & Foss, Rockland Lake	56
		65
		46
		52
		64
		50
3	J. S. Lane & Son, Weehawken, N. J.	16
		19
		19
		20
		18
		17
4	F. E. Conley, B, Munnsville	3
		4
		4
		5
		4
		3
5 & 6	F. E. Conley, A, Higginsville	18
		24
		19
		17
		17
		18
7 & 8	A. L. Swett iron works, Medina	12
		9
		12
		9
		10
		11

Test no.	Sample	No. of blows
9 & 10	Whitmore, Rauber & Vicinus, Rochester	7
		3
		4
		6
		4
		4
		5
11 & 12	Isaac Wagar, Saratoga Springs	2
		2
		3
		3
		2
		2
13 & 14	Helderberg cement co. Howe Cave	12
		10
		14
		9
		14
		14
15 & 16	Tomkins Cove stone co. Tomkins Cove	10
		11
17 & 18	Barber asphalt paving co. Buffalo	17
		20
		27
		36
		36
19 & 20	Brown & Fleming, Verplanck	0
		0
		0
		0
		0
		0

Test no.	Sample	No. of blows
21 & 22	Buffalo cement co. limited, Buffalo	17
		17
		20
		21
		29
		24
		28
		26
23 & 24	C. Worlock, Perryville	8
		11
		10
		11
		7
		10
		13
25 & 26	C. B. Whitmore, Lockport	2
		3
		6
		5
		5
		2
		3
27 & 28	W. T. Smith, Sharon Springs	37
		50
		65
		(imperfect) 12
29 & 30	The Carpenter Bros. Co. Guttenberg N. J.	50
		61
		49
		55
		65

Test no.	Sample	No. of blows
31	Newark lime & cement co. Rondout	12
		12
		14
		14
32	Mohawk Valley stone co. Palatine Bridge	9
		8
		10
		12
33 & 34	Dwight Babcock, Waterloo	16
		15
		17
		21
		19
		17
35 & 36	F. E. Conley, C, Oriskany Falls	24
		20
		25
		24
		24
37 & 38	R. Dunlop & Co. Jamesville	12
		13
		16
		14
		9
		10
		11
39 & 40	Callanan road improvement co. South Bethlehem	44
		50
		51
		40
		47
		45

Test no.	Sample	No. of blows
41 & 42	Chazy marble lime co. Chazy	21
		21
		26
		39
		36
		28
43	Round Island granite, (Daniel E. Donovan, New York)	10
		12
		18
		8
44	A. Shear & Co. Schenectady	41
		40
		35
		55
45 & 46	Hudson River stone supply co. New Hamburg	40
		35
		55
		46
		58
		56

The following additional tests were made for the state engineer, Hon. Edward A. Bond, and have been published in his annual report for 1900.

LOCALITY OF QUARRY	Name of stones	WEAR		Cementation value	Where used
		Coefficient	Per cent		
Clinton point, near Poughkeepsie	Gray limestone.	13.8	2.9	39	Used for base of 9 miles of roads in eastern New York, built by state in 1899 and 1900, and also for base and top of many roads in vicinity of New York

Additional tests (*continued*)

LOCALITY OF QUARRY	Name of stones	WEAR		Cementation value	Where used
		Coefficient	Per cent		
Little Falls, Herkimer co., Moss island, Mohawk river	Hornblendic gneiss	15.16	2.64	10	Used for base and top of 1 mile of Frankfort and Utica road, built by state in 1900
Glacial drift field stone, near Rochester, Monroe co.	Red sandstone	9.03	4.43	16	Used for base of Little Ridge road west from Rochester 6 miles, built by state during 1899 and 1900
Glacial drift field stone, near Rochester, Monroe co.	White sandstone	11.05	3.62	24	
Seneca Clark quarry, 12 miles south of Syracuse, near Lafayette, Onondaga co.	Gray sandstone	5.97	6.69	68	
National wall plaster co. Jamesville, Onondaga co.	Limestone	10.95	3.65	15	
Alvord quarries, near east line of town of Onondaga, Onondaga co.	Blue limestone	9.14	4.38	89	
Split Rock quarries, Solvay process co. town of Onondaga, also Indian quarries, on n. e. part Onondaga reservation, also Jamesville quarries near penitentiary of Onondaga co.	Gray limestone	6.2	6.45	22	Used for base of 2 miles of James st. and Cortland st. roads, near Syracuse, built by state in 1899 and 1900
Indian quarries, overlying the gray, on n. e. part Onondaga reservation	Blue limestone	5.99	6.68	33	
Buffalo cement co. quarries, in north part of Buffalo	Buffalo Plains limestone, with little embedded flint	8.29	4.82	67	Used for base and top of 33 miles of 16 foot roadways in 10 cities and towns of western New York during the years 1893 to 1900; used for base of 6 miles of state road near Buffalo
	Buffalo Plains limestone, with much embedded flint	9.66	4.14	94	
Bluestone quarry near Phoenicia, Ulster co.	Blue sandstone	11.17	3.58	39	Used for base and top of 6 miles of Ulster and Delaware road, built near Phoenicia by state in 1900
Waterworn stones from bed of Esopus creek, near Phoenicia, Ulster co. (similar to the quarry stones)	Blue sandstone	10.42	3.84	11	

Additional tests (*concluded*)

LOCALITY OF QUARRY	Name of stones	WEAR		Cementation value	Where used
		Coefficient	Per cent		
Smith & Post quarry, West Catskill	Sandstone, Esopus grit	8.52	4.69	60	
Turtle Pond quarry, Kaaterskill	Shaly gray New Scotland limestone	10.09	3.96	68	
Holdridge quarry, Kaaterskill	Becraft reddish gray crystalline limestone	7.61	5.25	56	

Tests of trap rock from report of Mass. highway commission 1900

LOCALITY OF QUARRY	Name of stones	WEAR		Cementation value	Where used
		Coefficient	Per cent		
Amherst Mass........	Diabase (trap)..	20.33	1.97	62	
Beverly Mass..........	Diabase (trap)..	16.71	2.39	14	
Boundbrook N. J.....	Basalt (trap)...	18.61	2.15	16	
Byram Station N. J...	Basalt (trap)...	26.93	1.49	31	
Great Notch N. J.....	Diabase (trap)..	18.59	2.15	36	
Rockland Lake N. Y..	Diabase coarse (trap)	17.79	2.25	13	
Lynn Mass............	Diabase (trap)..	18.17	2.20	......	
Meriden Ct............	Diabase (trap)..	15.49	2.58	28	
Milton Mass...........	Diabase (trap)..	22.77	1.75	34	
West Springfield Mass.	Diabase porphyry (trap)	22.14	1.81	17	
Millington N. J.......	Trap	19.64	2.04	53	
Averages	....	19.91	2.06	30	

GEOLOGIC MAP

The compilation of the base for the new geologic map by C. C. Vermeule C.E. is completed, and a contract for the publication of 2000 copies has been made by the state printer with the firm of Julius Bien & Co. The base is now being photolithographed, and proofs of two sheets have been submitted. The correction of the proof and the compilation and drafting of the geology are rapidly progressing, and it is expected that the new edition will be ready for distribution by the close of the next calendar year.

RECENT GEOLOGIC WORK IN FRANKLIN AND ST LAWRENCE COUNTIES

BY

H. P. CUSHING

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RECENT GEOLOGIC WORK IN FRANKLIN AND ST LAWRENCE COUNTIES

INTRODUCTION

The work done in Franklin county, since the preliminary report on the geology of that county published in the 18th annual report of the state geologist was written, has had for its main object the determination of the age and relationships of the augite syenite. As the tract of which Tupper lake is the center seemed to offer the most promise for this investigation, the work has been mainly in that vicinity. The establishment of the limits of this syenite area has necessitated carrying the work over into the eastern tier of townships in St Lawrence county. In addition, certain tracts in Franklin county, which had been left unvisited during the previous, hurried work, have received attention.

TOPOGRAPHY

The following notes on the topography are supplementary to the general discussion of that matter in the 18th annual report.

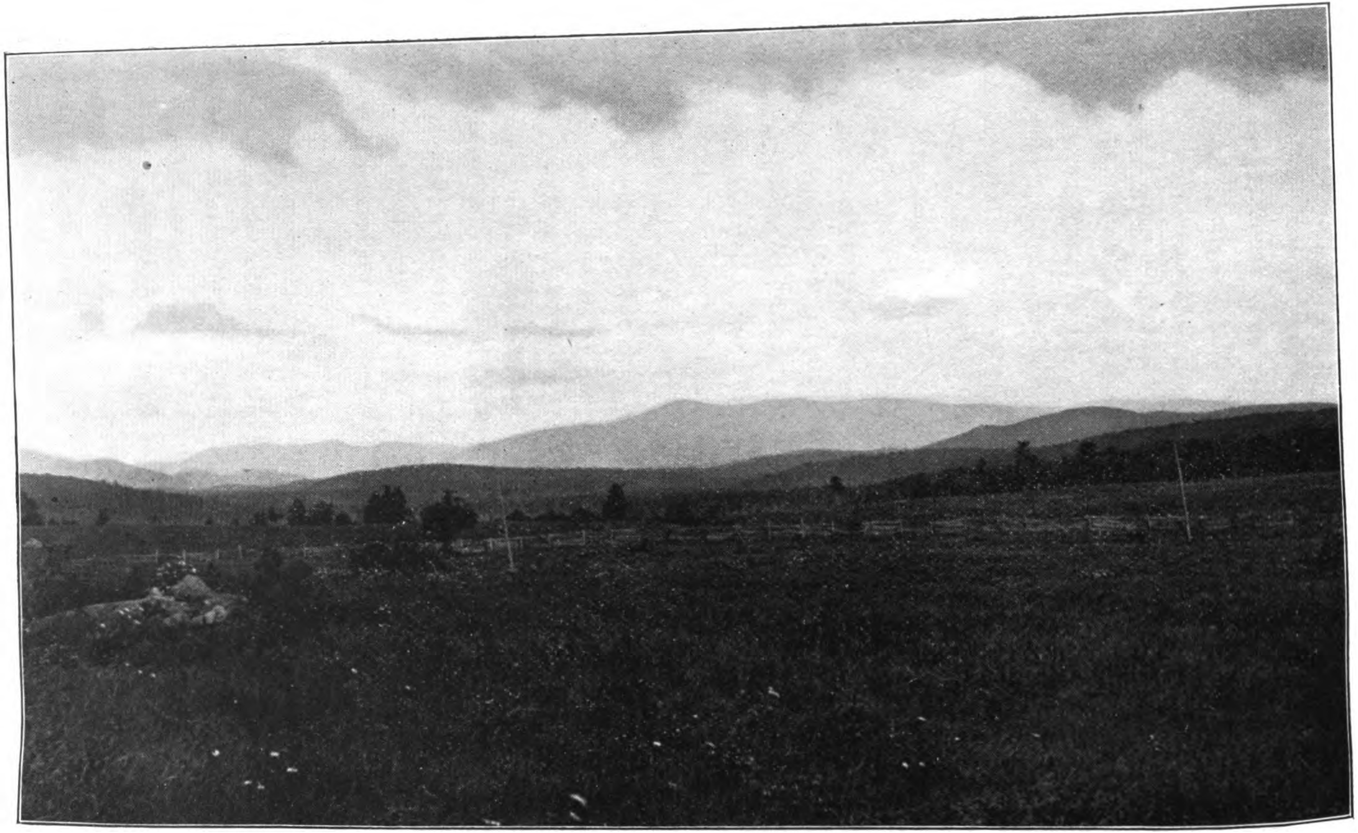
What may be called the "lake belt" is a most impressive feature in the Adirondack region. While ponds and small lakes abound throughout the district, they are much more numerous in this belt than elsewhere, and it has other peculiar topographic features. It may be said to extend from Loon lake in a south southwest direction to First lake of the Fulton chain. It is widest, and contains water bodies most numerously in southern Franklin county. It is sharply marked off from the district just east, the district of the high Adirondack peaks, by its low relief. Rock ridges are abundant but rise very little above the general valley levels, one or two hundred feet in general as a maximum. Hills of sufficient elevation to be locally dubbed mountains and to receive names are exceptional, though such do occur; even then, they will not bear comparison with the peaks to the east, where such are the rule. Wide tracts occur of very insignificant relief yet with abundant rock ridges.

The contrast with the district on the west is less striking, though of the same kind; there is much more diversity of surface than in the lake belt, though this western district bears no comparison with the eastern in ruggedness. These differences are most emphasized where the belt is widest, that is, in southern Franklin county. The writer is not sufficiently familiar with the belt in Hamilton county to know whether they are recognizable there or not, but there can be no question of their prominence in Franklin.

While this belt is depressed below the general level of the country on each side, no cause for its existence can be discovered in the character of its underlying rocks. The lake belt is not a belt of softer, or less resistant rocks, but is constituted of precisely the same rocks as the adjoining belts. Throughout a large part of it the surface rock is anorthosite, the most resistant of the Adirondack rocks. Augite syenite is the next rock in abundance as it is in resistance. The rocks of the lake belt are in no sense weaker than in the belts of higher altitude and greater relief adjoining.

The belt has many features which indicate that it was the path of a considerable preglacial drainage system. The alinement of Long lake, the Raquette river from Long lake to Axton, and Upper Saranac lake strongly suggests some such drainage valley. Along the river and Upper Saranac lake the low rock ridges trend east and west, at right angles to the main valley. The rocky points which project into the lake and the narrow bays which run in between them are precisely like interstream spurs and drowned tributary valleys, and many of the outlying ponds fall into alinement with the bays. Upper Saranac lake occupies a preglacial valley, dammed at its south end by a moraine and at the north by heavy sand deposits, which largely cover and hide a moraine there, so that the present outlet is at the side through one of the old tributary valleys. Lower Saranac lake occupies another such valley with a morainic dam at its northern end, apparently the same moraine by which Lake Placid is held up. Whether the basin of either of these lakes was deepened by glacial action or not can not be stated, but clearly such deepening is but trivial

Plate 2



H. P. Cushing, photo.

View southeast from a point not far from Tupper lake village and ½ mile east of that from which pl. 5 was taken, showing the Mt Seward range in the distance, and the Raquette valley on the left. The rock of the immediate foreground is augite syenite, but all the hills to be seen are of anorthosite. The Seward range is 15 miles distant. The foreground relief is that characteristic of the "lake belt", while in the background are the high ridges of the eastern Adirondacks.

if it exists. There is no sudden shallowing of the water in passing from the main lake into the bays, nor are the lakes themselves specially deep. They also contain numerous rock islands.

It is not believed that the presence of this preglacial drainage system in any way accounts for the topographic peculiarities of the lake belt. It is too sharply and abruptly marked off from the adjoining districts, that to the east particularly. It is, rather, believed that it is a structural depression. The evidence that the mountainous belt to the east is along an axis of comparatively recent uplift has been presented in the 18th annual report. Meridional faults of large throw are present; and it is thought that the uplift has been mainly effected by differential movements along the fault planes. The most reasonable explanation of the lake belt is that it is a dropped fault block, the district to the east having been largely uplifted with respect to it, that to the west much less so. The following topographic features seem to fall in line with this explanation.

In the eastern Adirondacks the altitude and relief are considerable, and the hilltops rise to various levels, with little sign of that concordance in altitude which might reasonably be expected in such an old land area, as marking periods of rest between the various uplifting movements which the region has undergone. In St Lawrence county, in the western Adirondacks, the numerous hills and ridges do attain very coincident altitudes and strongly suggest a peneplain with occasional monadnocks rising above the general level. In the pre-Cambrian district in central Ontario, which the writer had the pleasure of seeing last summer, under the guidance of Dr A. E. Barlow of the Canadian survey, the same accordant altitudes of the ridge crests were noted and commented on. The slight relief in the lake belt has been already noted. Now, recent uplifting in varying degrees along the meridional faults of the eastern Adirondacks would have largely obscured or destroyed the traces of such previous accordance there, and is thought to be the most probable cause of their absence. The known presence of such faults and the impressive fault scarps which are such a prominent feature in the eastern Adirondacks, though not conspicuous in the west, are corroborative features.

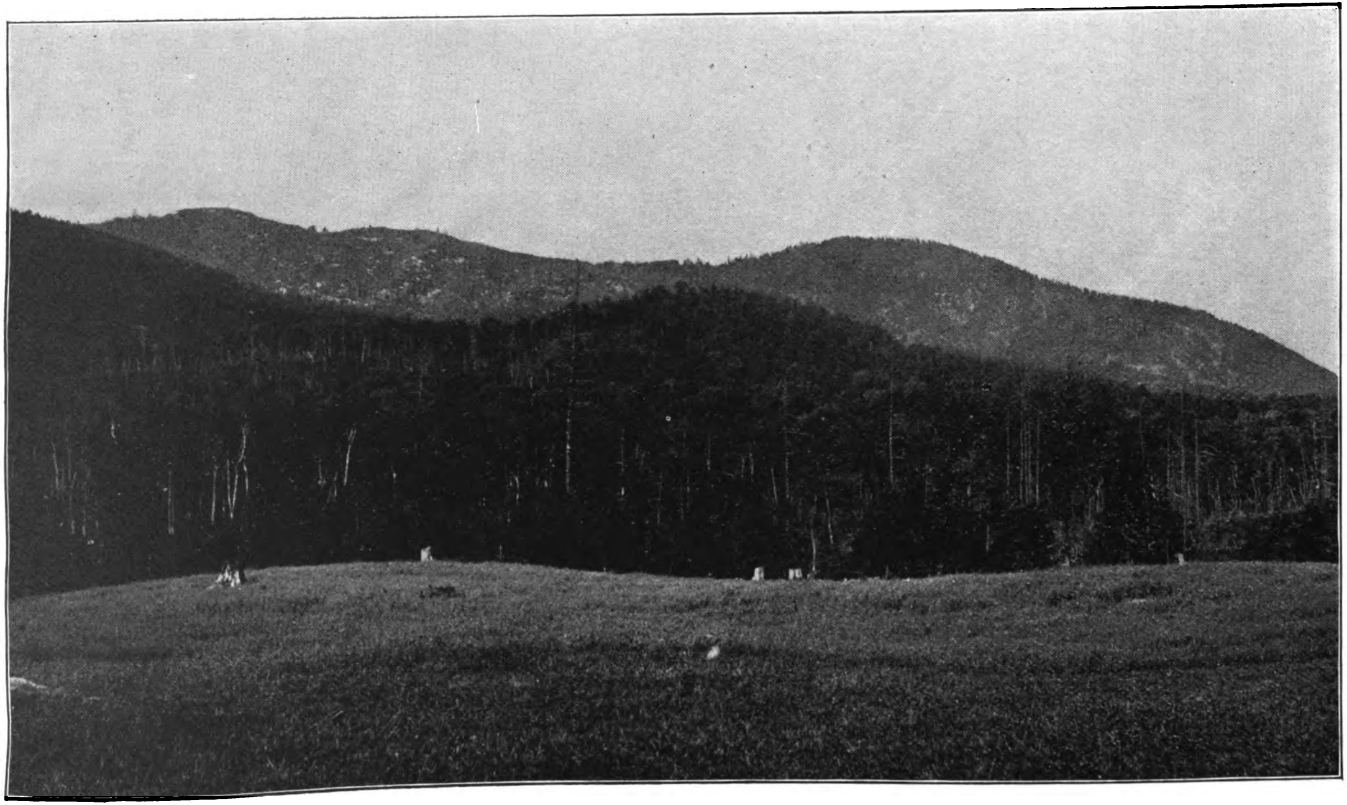
Most of the Adirondack rivers have their head waters in this lake belt, the Saranac, Raquette, St Regis, Moose and Beaver and some of the branches of the Hudson for example; and the divides between them are of the most insignificant character. Hence the great travel by boat through this section of the woods, the various carries (portages) being short and not difficult for the most part.

Sands in the northern portion of the lake belt

Throughout the northern part of this belt, from Upper Saranac to Loon lake and beyond, great quantities of sand are spread out. From Floodwood to Mountain View the roadbed of the New York Central and Hudson River railroad is on sand for the entire distance, a few fills and rock cuts alone excepted. The breadth of the sand belt is also considerable, and the rock ridges stand buried to their knees in it. In general the depth does not seem very great, though precise data are lacking. The host of ponds about the north end of Upper Saranac lake, including Lake Clear, Upper St Regis, and the north end of Upper Saranac lake also have their shores in large part or entirely of sand, and occupy hollows in the sand plain. The summits of morainic ridges sometimes protrude through the sand, and sometimes it is built up into an eskarlike ridge. All fine material is thoroughly washed out of it, and in the main it is very even grained, though holding occasional pebbles. Within a few feet of the summit there is often a coarse gravel streak from 1 to 3 feet in thickness, and occasionally the sand is capped by a coarse gravel. Cross bedding abounds. The ordinary sand is of a yellowish brown color, but the iron has often been leached out of the upper foot or two by the reducing action of the organic matter from the decaying plant roots, turning the color from yellow brown to white. Below, the iron has rapidly oxidized again and been deposited as a cement between the sand grains, forming a firm and quite impervious hard pan layer.

Plate 3

To face p. r28



H. P. Cushing, photo.

Mt Morris from the farm in Litchfield Park, looking north. The wooded spur to the east contrasts sharply with the burned mountain. The spur breaks down on the south in tremendous cliffs, 1000 feet high or more, mostly too steep for tree growth. The whole is of augite syenite. The low ridge in the foreground unfortunately obstructs the view but no better could be obtained.

These sands are up on the main watershed of the region, the lakes being the sources of the principal streams. There are no present streams which could have laid them down, and their source must therefore be sought in glacial streams which no longer exist. They can not have been deposited by lakes, unaided by streams, since the action of lakes on shores of glacial material is to wash away the sand and mud out into the lake and form gravelly or cobbly shores, such as those of Big Tupper lake. The sands away from the heart of the region are easy of explanation. They are along the present streams, and were laid down by them in aggrading their valleys, when overloaded with material, shortly after the ice retreat, probably aided by temporary ice dams, or, still lower down, were pushed out as delta deposits by these same streams in the higher levels of the bodies of standing water which occupied the St Lawrence and Champlain valleys in the closing stages of the glacial period. But the high level sands in the lake belt were transported by streams which no longer exist.

In the writer's opinion these sands were probably deposited as deltas in a large and irregular, shallow lake formed back of the ice tongue which occupied the lake belt during its slow retreat north, the material being furnished by the subglacial and englacial streams flowing into the lake at the ice margin. The massing of the sands in the north half of the belt, north of the watershed, indicates this. This remains as the only one of several working hypotheses that suggested themselves, which it has not been necessary to abandon for some reason or other; and no other hypothesis has suggested itself. The basin of Upper Saranac lake is thought to have been occupied by an ice tongue which, lingering longest where it was thickest, prevented the washing of sand into the hollow while the streams spread it out along the sides of the ice tongue. A majority of the hollows in which the other ponds lie would seem to have a similar origin, that is, blocks of ice were left stranded during the general ice retreat, the sands were washed over and around them, and then the slow melting away of the ice left the hollow in which the water now nestles. Loon lake, one of the larger lakes of this class, has its shores entirely of these sands, which are widespread around it.

The possibility that there was a considerable lake, formed in this belt back of the ice, must be borne in mind in further work in the region. Its presence is not necessary in order to explain the presence of the sands. These could have been formed equally as well in small, local ponds at the ice edge. The question needs more careful and painstaking work than it has yet been possible to bestow on it. Did such a lake exist, it would be far more deserving of the name "Lake Adirondack" than the water body in the Lower Saranac and Ausable valleys to which the name has been applied by Taylor.[1] That there were lakes in these valleys held up by the ice tongue which yet lingered in the Champlain valley is beyond question. But it is not certain that they were ever confluent, and they were not, strictly speaking, in the Adirondacks.

OBSERVATIONS IN THE ANORTHOSITE AREA

During the hurried field work of 1898, hurried because of the large area of which the writer's instructions required the mapping, the boundaries of the large anorthosite area of southeast Franklin county were followed and mapped, but the district was not sufficiently crosscut to exclude the possibility of the presence of considerable masses of other rocks within the heart of the area. With this possibility in mind and for the added purpose of ascertaining what signs of differentiation, if any, the mass showed, the district was revisited in 1899. The result of the work was to show that the area is constituted of anorthosite throughout, except for small intrusions of later gabbro and a few granite and syenite dikes of no great extent. It also showed a certain amount of differentiation, though very slight in amount when the size of the mass is taken into consideration.

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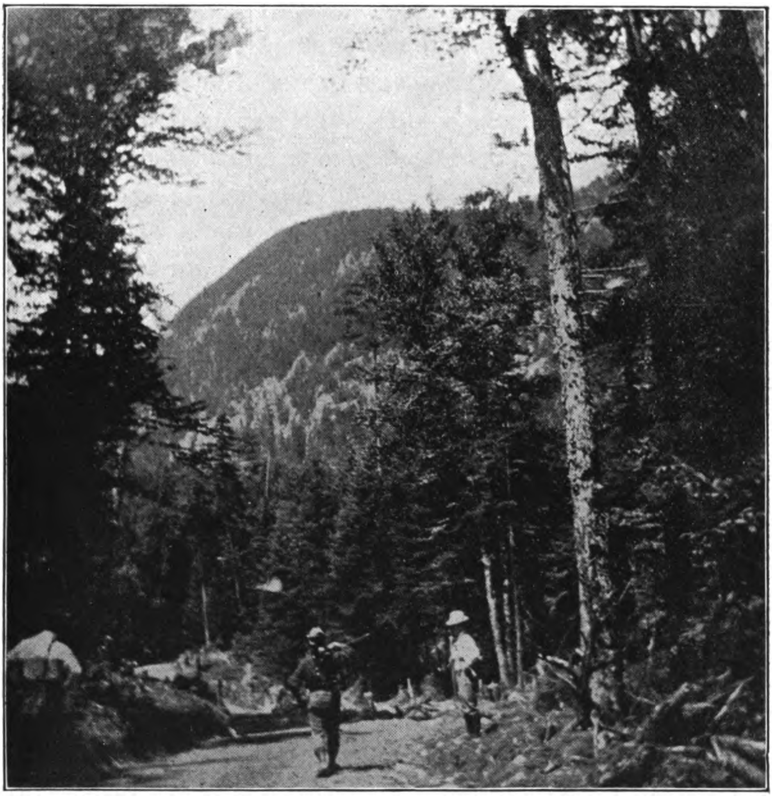
[1] Taylor, F. B. Am. geol. 1896. 19:392-96.



H. P. Cushing, photo.

Nearer view of the steep south face of the Mt Morris spur shown in pl. 5. The cliff rises quite sheer for some 800 feet and is probably a fault scarp.

General statement

Good exposures abound through most of the anorthosite district. The New York Central and Hudson River railroad cuts across it from Rollins pond to Saranac, affording numerous rock cuts in the low ridges which protrude through the sands, and which, except for an occasional small dike, show no other rock than anorthosite. The frequent ridges along the shores of Upper Saranac lake and the adjoining ponds show no other rock. The shores and islands of Lower Saranac and Round lakes, the ridges along the river from the lake to the village, the entire mass of Boot Bay mountain are of anorthosite exclusively except for a small intrusion of the later (hyperite) gabbro at the upper end of the lake. At Ampersand mountain, Stonycreek mountain, the country around the St Regis lakes and thence down the river to Brandon, St Regis mountain, everywhere in the district, the same features prevail. The uniformity of the rock is surprising, such variations as occur being mainly due to the amount of crushing which it has undergone and not to changes in composition. Occasionally the rock takes on a larger dark silicate content, more nearly approaching a gabbro, but, instead of its doing this as a whole, the change is local in its nature. There is however a usual change to a more gabbroid character as the periphery of the mass is approached, the ferro-magnesian silicates increasing considerably in amount, though seldom exceeding 15% of the rock and usually not constituting over 10%. Even this change is not universal throughout the mass, as quite typical anorthosite can be found close up to the edge of the intrusion. But the gabbroid phase far outweighs the other in this situation, while the reverse is true in the heart of the mass. Along with this change in amount of ferro-magnesian silicates goes also a change in the character of the feldspar. It usually becomes more acid, and quartz sometimes appears as well, but there is no regularity in the change. The recapitulation of some detailed observations is necessary in order to reenforce these general statements.

Section between Saranac and Lake Clear, N. Y. C. & H. R. R. R.

Between these two points the railroad closely follows the edge of the anorthosite mass. At first the Grenville rocks adjoin, but for most of the distance gneisses with a little augite syenite. It is possible that we are dealing with a fault contact, though by no means certain.

Just at Saranac the rocks are gneisses which are referred to the Grenville series. But the first rock cut (804), at the south end of Colby pond, shows anorthosite. Here, while portions of the rock have coarse and numerous labradorite crystals, the major part is thoroughly granular and, in its considerable content of dark silicates, recalls the hyperite gabbros. At least 20% of the rock is constituted of minerals other than feldspar, the minerals present being apatite, magnetite, garnet, augite, bronzite, hornblende, plagioclase feldspar and quartz. While one feldspar section shows equal extinctions of 20° from the albite twinning plane on both sides, the majority shows 10° or less, so that most of the feldspar is not more basic than andesin. There is only a little quartz, associated with garnet in the corrosion rims which have so often been described from these rocks. This rock is not necessarily more basic than the usual anorthosite, but would seem to have about the same silica with diminished alumina and lime and increased iron, magnesia and alkali percentage. Very similar rock shows in a ridge by the road some 300 yards east of the Ampersand hotel.

A second and long one, running to the point where the railway skirts the west extremity of the pond (805) is 40 rods beyond this cut. In this the rock is at first fine grained and looks precisely like the last, but it becomes progressively coarser and more porphyritic, becoming quite typical anorthosite at the farther end. Midway of the cut is a dike of apparent gabbro some 30 feet wide (805A). In the coarse rock at the farther end of the cut the large labradorites show flow structure, having a parallel alinement. Here is also an apparent dike of granite, though it may be merely a huge inclusion, its great difference in width on the opposite sides of the cut favoring this view.

When the apparent gabbro from the middle of the cut is more carefully examined, it is seen to be quite peculiar. It holds some 30% of non-feldspathic minerals, zircon, titanite, apatite, pyrite, magnetite, garnet, augite, biotite, hypersthene and hornblende and at least 5% of quartz. So far as can be told from the presence or absence of twinning there is barely a scrap of plagioclase in the rock, the feldspar consisting of irregular intergrowths of two different feldspar species, probably orthoclase and an acid plagioclase. Two little cores of plagioclase within these feldspars give the impression that all is secondary and due to the alteration of a plagioclase. This rock will be reverted to later when a similar rock from another locality is under discussion. As it stands, it has more affinities with the augite syenites than with the anorthosite. Its boundaries are not well exposed, so that it is not certain that it is a dike, though this is most probable.

In the third cut, 1½ miles from Saranac depot, there is also shown an association of granular anorthosite gabbro (976) running into coarse phases. Here also is a crushed and altered strip of white and decayed looking rock, which proves firm and merely altered, not decayed. The feldspar has gone to saussurite, an alteration product consisting largely of zoisite. Considerable epidote has developed locally, likely from the original augite. In much of this rock the alteration is only partial, feldspar cores remaining. In these, extinctions up to 22° from the albite twinning plane indicate labradorite as the feldspar.

At the fourth cut, nearly 2 miles from the depot, the rock is mostly of the granular anorthosite gabbro type, few labradorite augen remaining (977). The cut is not extensive.

The fifth cut commences a little over 2½ miles from the depot and is 65 yards long. Here the rock (978) is excessively jointed and sheared, furnishing easy passage for underground waters, and alteration is on a much greater scale than usual. The finer grained portion is wholly altered, but unchanged cores remain in the large labradorites. These show the attack to have been along the outer boundaries and the cleavage cracks of the feldspar individuals, working thence inward, underground water being the agent which effected the alteration, the action occurring long ago and in depth. The dark silicates have gone to chlorite and serpentine, the feldspar to saussurite, much zoisite having developed along with chlorite, muscovite or paragonite, and a colorless, weakly refracting, strongly doubly refracting biaxial mineral, with highly inclined extinction and rather small axial angle, whose identity has not been determined. Considerable epidote has developed locally. In the cut is some white quartzose gneiss, most probably an inclusion from the adjacent Grenville rocks, and some coarse granitic gneiss, likewise a probable inclusion. There is also an 18 inch dike of gabbro norite, probably a thoroughly metamorphosed dike of the hyperite gabbro.

The next three cuts are of small extent, but all show anorthosite gabbro rather than anorthosite, both fine and coarse varieties occurring.

There is a 30 yard cut in coarser and more typical anorthosite than the preceding $4\frac{3}{4}$ miles from Saranac. A diabase dike in three branches is exposed in this cut, these dikes being rare so far west.

The last cut is mile from the Lake Clear depot (984). Here are the same phases as before, though the granular rock differs from that in the previous exposures, both to the eye and under the microscope. To the eye the main difference is the absence of garnet, corrosion rims not being present, so that the rock lacks the peculiar appearance which these invariably give. Apatite, magnetite, augite, hypersthene, hornblende and a basic plagioclase are the mineral constituents, and the rock is quite certainly more basic than any of the preceding. The feldspar makes from 85% to 90% of the rock, is beautifully twinned with both albite and pericline lamellae, and shows maximum equal extinction in sections perpendicular to the albite twinning plane of 33°, with nearly all such sections in the slide showing from 25° to 30°; so that the feldspar is in all probability bytownite, instead of the usual acid labradorite of the anorthosites.

Summary of section. The main rock in this section along a part of the boundary is anorthosite gabbro, rather than anorthosite, which in the main seems neither more acid nor more basic than the normal rock, but differs in containing from 10% to 30% of ferro-magnesian silicates, whereas the usual anorthosite rarely has a 5% content of these; but the greater basicity thus indicated is counteracted by the more acid character of the feldspar and the frequent presence of quartz. Also, this border rock shows basic phases, that from the last cut being an example. No analyses have been made of the rocks of this section, but they are closely related to the quartz anorthosite gabbro described in the report on the Mooers sheet in the 19th annual report, and to other rocks shortly to be described, analyses of which are available. There is also shown a probable large dike of a rock whose affinities are with the augite syenites rather than the anorthosite.

Exposures in the vicinity of Saranac

Along the Saranac river between the lake and the village are repeated ledges which furnish a good section from well within the anorthosite area out to its boundary. This section shows a transition from quite typical anorthosite, such as that at the state dam, into an anorthosite gabbro similar to that just described; it is however complicated by considerable masses of gabbro, which are probably slightly later in age and referable to the hyperites.

Near the village the contact between the anorthosite and the adjacent gneisses is exposed. The rock ridge which lies somewhat south of the road from the Algonquin to the village, and runs parallel with it, forms the boundary of the anorthosite in this direction and is composed of a quite granular anorthosite gabbro, in which in general labradorite constitutes from 80% to 90% of the rock, and in which hornblende and biotite are often present to the exclusion of augite. The new reservoir, back from the village toward this ridge, is excavated in rock (974) exposing black, flinty, fine grained gneisses, which have the structure of granulite and the mineralogy of gabbro diorite, though the feldspar extinctions indicate andesin, and at least half is untwinned. These gneisses are all cut up by a later red syenite and are tremendously shattered by very frequent joints. The gneiss is regarded as of Grenville age on account of the association of a similar gneiss with the undoubted Grenville rocks east of Colby pond. The syenite is in thin sheets intruded along the joints. It contains only sporadic quartz and is a rare rock in the Adirondacks.

Only a few yards south of the reservoir the contact between the anorthosite and what is taken to be the same gneiss is exposed (973). The contact is sharp, and the anorthosite includes great lumps of the gneiss and is unquestionably the younger rock. The gneiss differs from that at the reservoir in containing hypersthene in addition to augite and hornblende so that it is a gabbro norite rather than a gabbro diorite, but all such gneisses in the Adirondacks show rapid mineralogic change within short distance. The intruded syenite is also lacking here, but the distance from the reservoir is so slight that it is thought to be certainly the same gneiss. The anorthosite at the contact has still 90% of feldspar, but in addition to the labradorite, which gives slightly lower extinctions than usual, barely reaching 20%, there is considerable untwinned feldspar which consists of a blotchy intergrowth of orthoclase and albite, the intergrowths having none of the regular appearance of the usual microperthite. This rock represents, then, an intermediate stage between the usual granular anorthosite norite of the boundary and the dike rock from the second cut of the previous section, in which the feldspar is wholly of this type. This same rock is also met elsewhere in the district.

Summary of section. This section is at right angles to, instead of parallel to, the boundary, and shows a passage from normal anorthosite to granular anorthosite gabbro as the boundary is approached. It also exhibits a contact against the adjacent gneisses, which shows the anorthosite to be the younger. It farther shows rocks intermediate between anorthosite and such microperthite rocks as were described in dike form from the preceding section, indicating their close relationship to the anorthosite in origin and in time.

Section west from Saranac Inn station, N. Y. C. & H. R. R. R.

Unlike the previous sections this lies wholly well within the anorthosite mass not approaching the boundary anywhere. 40 rods east of the depot is a small cut in ordinary anorthosite. The first cut west of the station is 1½ miles distant and is again in ordinary anorthosite (950), that is the rock consists wholly of labradorite except for trivial amounts of augite, garnet, magnetite and pyrite or chalcopyrite, which seldom comprise as much as 5% of the rock and usually much less. The rock is much shattered by closely repeated vertical joints in two sets, one set of which is often curved, producing wedgelike blocks, and the adjacent rock surfaces are commonly slickensided, showing that we are dealing with a zone of slip faulting. A little over ¼ mile beyond is a 50 yard cut in precisely similar material, equally shattered and sheared.

At 2¾ miles from the station is another 50 yard cut in a ridge which runs down with a cliff face to the north shore of Hoel pond. The rock here (952) is more thoroughly granulated than the preceding, but consists of 99% labradorite, holding otherwise a little pyrite, zircon, a few small augite inclusions and a little quartz feldspar intergrowth of the quartz *vermiculé* type. The rock is not so excessively jointed as in the previous cuts, being more normal in this respect. Besides the two joint sets there is also a slip cleavage giving slickensided surfaces.

At a little more than 3 miles is a cut 120 yards long, again in typical anorthosite (953) showing an interesting altered strip a few feet wide in which the feldspar has wholly gone to scapolite. This is much less altered than the general appearance of the rock would indicate, though the scapolite fragments are kaolinized outwardly and along the cleavage cracks. The alteration has not wholly destroyed the original, opaque, rodlike inclusions of the labradorite which appear here and there, sometimes quite numerously, in the scapolite. Adjoining the scapolite strip, the anorthosite is excessively sheared, cleaving along slickensided faces, which follow one another at intervals of fractional parts of an inch; the scapolite zone evidently marks the strip of maximum disturbance and change.

At 3¼ miles is another long cut, 140 yards in length. At the west end is a dike of gabbro (954B) 8 feet wide, of interest from several points of view. It contains some 30% to 40% of augite, hornblende, bronzite, magnetite and apatite, some little quartz, and garnet rims of the honeycomb type between the magnetite and feldspar. The feldspar is largely of the blotchy intergrowth type, but considerable plagioclase remains, sufficient to show that it is andesin and that it alters to the other feldspar. There is much unaltered andesin in the ground mass however, and this seems to have been largely recrystallized. Again, in this cut is abundant evidence of slip faulting along one set of the joints. Here the larger cracks contain anorthosite fragments cemented by deposition of calcite followed by chalcedony. These vein fillings are mostly only fractional parts of an inch in width, occasionally reaching 2 or 3 inches.

At 3¾ miles is another long cut 180 yards. Neither this nor the previous one is a continuous cut, but shows low anorthosite ridges, with summits some dozen feet above the roadbed, separated by sand-filled depressions. The rock here (955) is the same shattered anorthosite of the previous cuts. Garnet is more prominent, and the rock is not quite so prevailingly feldspathic. Near the west end of the cut is a probable inclusion of coarse granite. At 4 miles is a small cut exposing very coarse anorthosite, much less shattered than the foregoing.

Summary of section. This section will answer for the type of many well within the anorthosite mass. Except for occasional intrusions of gabbroid rocks and inclusions of granite the rock shows great uniformity. The feldspar is pretty uniformly an acid labradorite with extinction maxima of 20° to 22°, but in nearly all cases there is some little of the untwinned feldspar intergrowth present. This may become of quite respectable amount, as illustrated by exposures some 3 miles south of the line of the section, between Upper Saranac lake and Follensby Clear pond, where the rock is slightly more gabbroic. In fact, increase in amount of this sort of feldspar usually accompanies increasing content of ferro-magnesian silicates.

But the interesting matter in this section is the dike in the 140 yard cut (954B), interesting because it brings out clearly the relationship of the syenitic rocks described from the preceding sections, to the anorthosite, since we have here a strictly intermediate rock, resembling precisely those whose feldspar is wholly of the anorthoclase type yet with much plagioclase present in addition.

Exposures about Brandon

The little hamlet of Brandon on the New York and Ottawa railroad is included in the Rockefeller purchase and is now in process of demolition. It lies close to the anorthosite boundary, but exposures are not as frequent nor as good as could be wished. Around the St Regis lakes and thence down the river toward Brandon the exposed rock is of typical anorthosite, the feldspars constituting from 95% to 99% of the rock and showing extinction maxima of from 22° to 26° in the various slides. Just about Brandon it varies from the type, though still consisting mainly of feldspar. The proportion of untwinned feldspar has however considerably increased, and some of the blotchy intergrowths are evident, indicating that anorthoclase is becoming prominent.

A hill ½ mile north of Brandon is constituted of amphibolitic and granitic gneisses, and Buck mountain, 2 miles to the west, is composed of the same rocks, showing that at Brandon we are near the anorthosite edge. Yet at Indian rock, a small isolated exposure on the river 2 miles northwest of Brandon and lying within the gneiss zone just mentioned, the rock is again anorthosite (713). It is wholly gneissoid, and in addition to the feldspar contains some 5% to 10% of hornblende and magnetite, the hornblende commencing to alter to biotite. The major part of the feldspar shows albite, twinning with 21° maximum extinction. There is also some non-twinned feldspar, which is probably anorthoclase. From its situation this rock is regarded as a probable offshoot from the main mass, likely of the nature of a large dike. It is cut by two dikes, one of fine grained and the other of coarse red granite.

To the southwest of Brandon, in township 16, the most wester anorthosite outcrops are those at the old Ducey lumber camp Here the rock (941) is much crushed, though abundant labradorit augen remain. Minerals other than the feldspar make some 15 of the rock. These are as usual hypersthene, augite, hornblende magnetite, apatite, zircon and titanite, with a little occasiona pyrite. Hypersthene here is unusually prominent for an Adirondack anorthosite, much exceeding in quantity the augite and hornblende together, so that the rock is an anorthosite norite rather than an anorthosite gabbro. The feldspar is nearly all twinned and apparently all labradorite. This rock differs from the usual border rock in that the increase in amount of dark silicates is not accompanied by increasing acidity of feldspar. It is more nearly like the rock from the last cut in the Saranac-Lake Clear section (984) than any other, though not quite so basic as that, the feldspar extinctions only reaching 24°.

General summary of previous sections

The previous detailed observations are sufficient to establish the fact that there has been some slight differentiation in the anorthosite mass since reaching its present resting place, the general result being that the rock becomes an anorthosite gabbro in its outer parts, sometimes becoming more basic than the general mass of the rock, but in general retaining about the same silica percentage, increase in the amount of basic minerals being accompanied by increasing acidity of the feldspar; that the final result of the differentiation in this direction is the production of a rock of gabbroic appearance and with large content of ferromagnesian silicates, in which the feldspar is no longer plagioclase but anorthoclase, so that the rock can no longer be classed with the gabbros; that in considerable part the latter rock solidified slightly later than the main mass and was injected into it in the form of dikes, which are most abundant about the edges of the mass but also occur well within it. It further appears that away from the periphery the anorthosite is quite homogeneous in composition. Occasional bands of gabbro cut it, and occasionally there is a local enrichment in ferro-magnesian silicates, but these are exceptional. There are no such great masses of gabbro as Kemp has shown to exist in Essex county, involved with the anorthosite.[1]

OBSERVATIONS ALONG THE SOUTHWEST ANORTHOSITE BOUNDARY

Within the past four years Prof. Kemp, Prof. Smyth and I have all observed considerable areas of rocks, in our respective districts in the Adirondack region, which much resemble the anorthosites in some of their phases and were at first classed with them. These rocks have great importance in the region, and their true nature was realized by all at about the same time and independently.[2] Like the anorthosites, they are highly feldspathic rocks, but differ from them in nature of the feldspar, so that they must be classed with the syenites rather than as members of the gabbro family. All of us agree that these syenites are younger than the Grenville rocks. In Smyth's district anorthosites are practically absent, so that opportunity for determining the relative ages of the two rocks is not forthcoming there. Kemp seems disposed to class them with the main mass of the gneisses and hence as older than the anorthosite. The writer noted the intermediate rocks which have been described in the previous pages and was led to believe that the two rocks were closely related in age, were derivatives from the same great igneous magma, and even in part derived from differentiation of the anorthosite itself. In the hope of settling the question, considerable time has been given to observations along the southwest anorthosite boundary, as it immediately adjoins a large syenite area in that direction. Exposures are however few near the boundary and have not sufficed to give a definite answer to the question at large, though clearly bringing out the fact that some of the syenite at least is closely related to and slightly younger than the anorthosite, thus falling in line with the detailed observations already set forth.

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[1] *See* map fronting p. 398, 19th an. rep't U. S. geol. sur. 1899. pt 3.

[2] Smyth, C. H. jr. Geol. soc. Am. Bul. 6 : 271-82.

—— —— N. Y. state geol. 17th an. rep't. 1897. p. 471-86.

Kemp, J. F. N. Y. state geol. 17th an. rep't. 1897. p. 507, 512, 515.

Cushing, H. P. Geol. soc. Am. Bul. 10 : 177-92.

—— —— N. Y. state geol. 18th an. rep't. 1898. p. 105-9.

Section from Tupper lake to Rollins pond, N. Y. C. & H. R. R. R.

The rock about Tupper lake is augite syenite, but anorthosite is reached within 3 or 4 miles to the north and east, with no other rock intervening, so that it was hoped that traverses from one to the other would disclose outcrops which would give the clue to the time relations. There are but two convenient lines of section.

For the first 3½ miles from the depot at Tupper Lake Junction there are no rock cuts along the railway, but occasional ledges are found in the woods within ½ mile of the track. These are all of a greenish or brown gneiss which is clearly referable to the augite syenite, but the outcrops are of the unsatisfactory sort which prevail in the woods. At 3½ miles is a low rock cut of meager dimensions which furnishes however fresh material (906). The rock must be classed with the augite syenite, though a variant from the type in that it is somewhat more basic, with extra large content of ferro-magnesian silicates for these rocks, containing some 30% of them instead of the 15% to 20% of the normal rock. The difference is but slight, however. Much magnetite and garnet are present, considerable augite and hornblende, less bronzite, a little biotite, and the usual zircon and apatite. There is some 5% of quartz. The feldspar is two thirds microperthite, the remainder showing no sign of twinning or of intergrowths. There is a bit of oligoclase, and there are some small patches of quartz *vermiculé*. The microperthite often shows a further intergrowth of micropegmatitic aspect, the one feldspar exhibiting no sign of the microperthite intergrowth, the other showing it beautifully and the whole producing a striking combination in thin section. It is clearly a growth of two feldspars, notwithstanding the resemblance to micropegmatite. ½ mile beyond another ledge of syenite is found in the woods, ¼ mile northwest from the track, but it does not furnish fresh material (902). It is however of the same type as the rock from the cut.

At 4½ miles from the junction is a rock cut in the first anorthosite seen (903). It is of the anorthosite gabbro type and interesting in showing all gradations from quite coarse to very finely mashed rock. In fact, the granulated portions are much finer grained than usual, have a greenish tinge, and in combination with the dark blue black labradorite augen produce a very striking looking rock.

A small cut ¼ mile farther furnishes similar and very interesting material (905). The rock is pretty thoroughly granulated, though numerous small labradorite augen remain. The granular portion has a strong resemblance to the usual augite syenite. The rock is an anorthosite gabbro, with 10% to 15% of minerals other than feldspar, these being the usual magnetite, garnet, augite, hornblende, apatite, zircon and pyrite. A little quartz is present as a by-product of the feldspar-magnetite interaction which resulted in the garnet formation. Of the feldspar in the slide (none of the large augen appearing) slightly less than one half shows albite twinning, the maximum extinction found in the several sections properly cut being 12°, indicating andesin. Of the untwinned feldspar the larger portion shows intergrowths, partly microperthite and partly of the micrographic type. The intergrowths seem distinctly primary, though some of the andesin shows a tendency toward such intergrowths as well. Optical tests of cleavage pieces of the large augen show these to be labradorite.

A portion of the rock was crushed, and specific gravity determinations of these feldspars were made. At 2.659 the first considerable quantity of feldspar fell, and this is closely the gravity of acid andesin. The last and greater part of the remainder fell at 2.569, though, as the liquid was slowly diluted down to this strength, a little feldspar fell from time to time, indicating the presence of a slight amount of intermediate composition. A chemical analysis and further discussion of this rock, as well as of that from the 3½ mile cut (906), will be found on a later page.

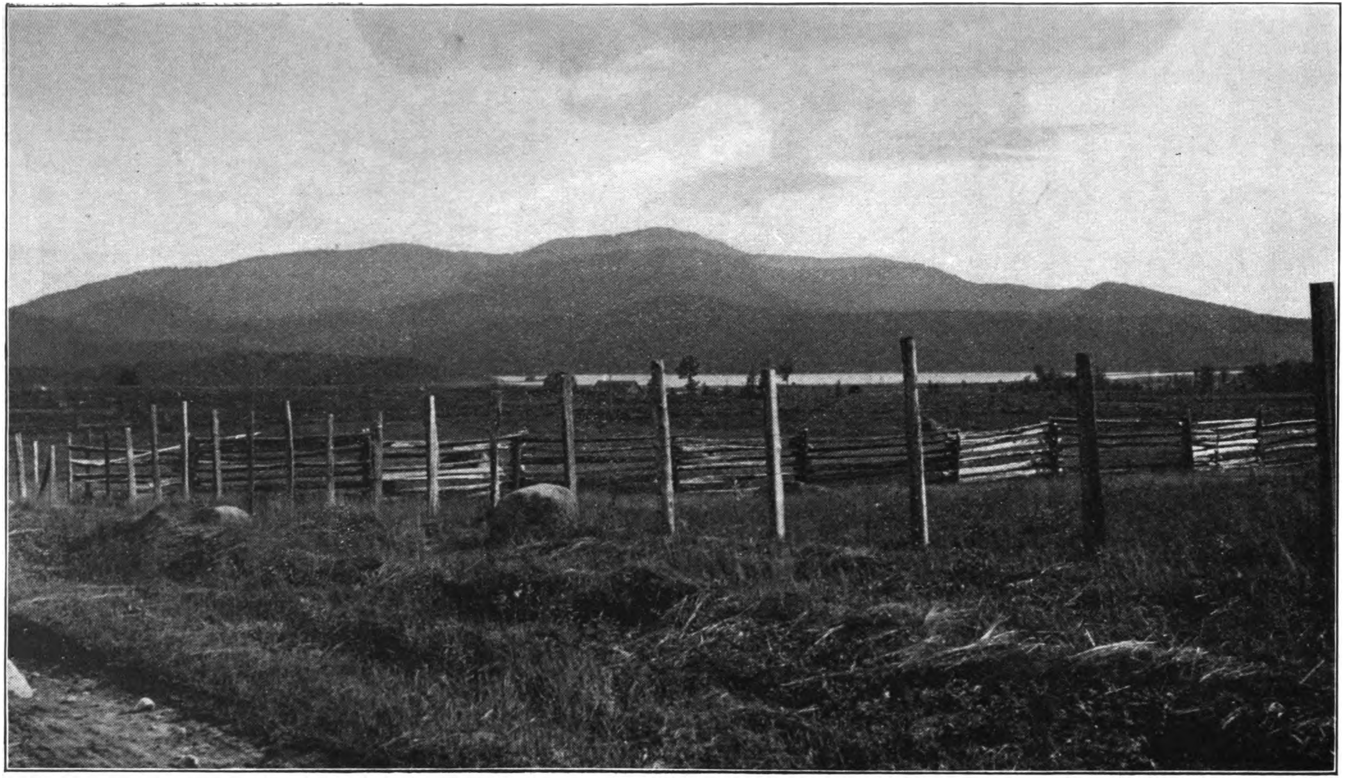
At 5 miles from the junction and shortly before reaching Rollins pond is another cut in anorthosite gabbro, specially rich in garnet, and with many and large labradorite augen remaining (904). Beyond, the rock passes into ordinary anorthosite.

Summary of section. This section comes nearest of any to affording a transition from anorthosite to augite syenite. The syenite, shown best in the cut at 3½ miles (906), is unquestionably the same rock as that found in dikes cutting the anorthosite in the Saranac (805A) and Saranac Inn (954B) sections. Yet it is here found as a border phase of a large syenite mass. Further, the rock from the cut at 4¾ miles, though to be classed with the anorthosite, shows strong leanings toward the other rock and is an unmistakable intermediate type, as the chemical analysis will more strongly emphasize. It is also very like the border rock near the reservoir at Saranac (973). The two furnish strong evidence of the close relationship of the two rocks, the anorthosite and syenite.

Section from Tupper Lake village toward Wawbeek

Just in and about Tupper Lake village are many exposures of augite syenite gneiss. In the village a quarry has been opened for road metal and foundation stone, and this furnishes the freshest and most satisfactorymaterial (999). It is in all respects quite typical augite syenite gneiss. There is present some 10% of dark silicates, hornblende, augite, magnetite and bronzite, in order of abundance, though the quantities vary much from place to place. There is considerable zircon and but little apatite, as is usual in this rock. Some 5% to 10% of quartz is present and the remainder of the rock consists of feldspar, mostly rather poorly marked microperthite, though the micrographic intergrowth is at hand as well and sometimes the two are combined. There is also a little oligoclase.

These syenite exposures only extend for ½ mile east of the village, and beyond for 3 miles no rock protrudes through the heavy drift filling. But not far south of the road a ledge of the same rock shows by the river, 2 miles from the village. 1 mile farther up the river, the first anorthosite is found, so that we have here, along the boundary, a gap of a mile in which no exposures are forthcoming.



H. P. Cushing, photo.

Looking south across the Raquette valley to Mt Morris, from a short distance south of Tupper lake village. Big Simons pond is seen in the center of the view, Little Simons pond lies in the notch on the left and the Tupper lake valley lies on the right.

Soon after passing Halfway brook, and the west line of the Cornell forestry tract, the first anorthosite is seen along the road (935), and a large ledge appears in the woods a short distance to the north. The rock is a medium coarse anorthosite with a considerable dark silicate content, being distinctly of the anorthosite gabbro type. The exposure by the road is merely a smooth glaciated surface, from which it is exceedingly difficult to procure specimens. But it is a most interesting exposure, exhibiting the anorthosite as all cut up by a finer grained rock, which is unmistakably younger and intrusive into the anorthosite. It is thoroughly continuous and separates the anorthosite into great horses. This rock strongly resembles the usual augite syenite and proves to be of that type, somewhat more basic than the usual run of the rock, though quite comparable in that respect with the rock from the first cut along the railway north of Tupper lake (906) and with that from Colby pond (805A). It holds uncrushed feldspar augen rather more numerously than the usual syenite and of larger size, though quite comparable with some phases of the syenite. It is quite certainly the same rock as that already described, but here, instead of grading into the anorthosite or cutting it in single narrow dikes, it has invaded it in force, wedging asunder great blocks of the anorthosite, which it surrounds. An analysis of this rock appears on a later page.

Nearly a mile farther east the road takes a curve to the south around the end of a massive rock ridge, showing outcrops by the road (937) and also a short distance back in the woods (936). The former exposures are of anorthosite norite, rather than gabbro, with much variation in the dark silicate content and in the degree of granulation. They are cut by a large dike of a curious, dark gray porphyry with reddish feldspar phenocrysts, which seems of considerably later date and of syenitic make-up. Such dikes have also been found in other parts of the region cutting the anorthosite. They may possibly be nearly contemporaneous with the hyperite gabbros, forming their complementary types. They have been somewhat metamorphosed and are earlier than the syenite porphyries associated with the diabases. A similar dike is well exposed near the road from Paul Smiths to Brandon, in a field just north of the road on Hall's farm, about a mile west of Keese's Mills.

The other rock (936) is augite syenite of the same type as that just described (935), though here its field relations to the anorthosite are not exhibited. It has a somewhat larger content of dark silicates, and quartz is practically absent, but the feldspars are of the same peculiar intergrowth type. It is unquestionably the same rock and in all probability intrusive into the anorthosite, as that is.

South of these exposures, along the river at Tromblee's and between, are ridges with many exposures, all seen being of anorthosite gabbro.

Summary of section. Though in this section lack of exposures prevents ascertaining the possible existence of gradations between the anorthosite and syenite, the cutting of the anorthosite by syenite of precisely the same type as that found in the previous sections is well shown; and, while in those only occasional small dikes have been forthcoming, here the rock is found invading the anorthosite in considerable force. The evidence of this section and the preceding as well is demonstrative that there is in the region a considerable body of augite syenite that grades into the anorthosite, but that also was, as a whole, slightly later in cooling, so that it has invaded the main body of the anorthosite in the form of dikes. The presence of these dikes would seem fatal to the theory that the intermediate rocks were produced through the absorption, by the anorthosite magma, of a certain amount of an earlier syenite, since it is difficult to understand how the border rock thus produced could remain molten longer than the parent mass. The phenomenon would be explicable however on the assumption that the syenite was the younger, and that the intermediate rock was produced by the melting away and absorption of a certain amount of the anorthosite. Whether the intermediate rock has been formed in this fashion or by direct differentiation is uncertain, but in either case the later date of the syenite is a necessary conclusion.

RELATION OF AUGITE SYENITE TO GNEISS

Though the observations so far recorded would seem decisive as to the time relations between these two rocks, the contacts of the Tupper lake augite syenite in other directions are with gneisses, into which they grade and fade out, as if they represented portions of the same great complex, and these are the usual phenomena in the Adirondack region, the augite syenite seldom, if ever, showing sharp boundaries against any rocks, with the single exception of the Grenville limestones and associated schists and gneisses. The presentation of a few detailed observations will be helpful as a prelude to the discussion of the phenomena.

Section from Tupper Lake Junction to Horseshoe

Nearly a mile below the depot at Tupper Lake a cut in a massive rock ridge (898) shows a coarsely gneissoid rock, approaching granite in composition, in which are occasional amphibolite streaks which may represent either drawn out inclusions or segregations. Along with the red rock, and grading into it, is much green rock which closely resembles the red except for color. The green rock can not be distinguished from ordinary augite syenite of the acid type, consisting mainly of feldspar, but with some 15% to 20% of quartz and some 10% of bronzite, hornblende and augite, named in order of abundance, and the usual zircon, titanite, apatite and magnetite in small quantity. Except for a little oligoclase the feldspar is all alkali feldspar, intergrowths of orthoclase and albite with the micrographic form more prominent than the microperthitic. The red rock is more quartzose and the pyroxenes have disappeared, but it appears to grade into the other and represent its granitic phase. Precisely similar admixtures are found in Litchfield park and elsewhere near the syenite periphery.

Beyond this point the railway soon crosses the Raquette river and then turns westward along it, no further outcrops appearing for more than a mile. At 2¼ miles from the depot is a cut in a greenish gray rock (1000), mainly very fine grained and gneissoid but having also coarse bands, which does not appear like the usual augite syenite and is referred to it with hesitation in my field notes. The thin section shows it to depart from the syenite in several respects. The coarse bands are more acid than the rest and probably represent pegmatitic portions. The slide shows some 35% of quartz, 10% of dark minerals, hornblende showing incipient alteration to biotite, magnetite and a little pyrite, and the remainder of feldspar, mainly microperthite. The finer gneiss is characterized by much deep orange titanite and emerald green, pleochroic augite, two minerals quite characteristic of certain red, acid gneisses of the region, which are often closely associated with magnetic deposits. Such red gneisses appear shortly, going down the river, and this rock clearly belongs with them. Otherwise its minerals are as in the coarse rock, though quartz constitutes only some 10% to 15% of the whole. The structure is like that of the usual gneiss rather than that of the augite syenite.

At 2¾ miles is a cut in red, fine grained gneiss (1001), with many pegmatitic and some very hornblendic bands, which is a quite typical sample of the red, titanite gneiss just referred to. It will be more fully described as it occurs at Piercefield, a little beyond. Its minerals are the same as those of the green gneiss of the preceding cut, though it is somewhat more quartzose. A 5 foot dike of beautifully fresh, olivin diabase cuts this red gneiss and is of additional interest, since it is the most westerly of these dikes that I have seen in the Adirondacks. The locality is close to the boundary line between Franklin and St Lawrence counties; and, with the imperfect maps in hand, it was impossible to be certain in which the exposure occurred. If in St Lawrence, it will be the first of these dikes to be noted from that county so far as I am aware.

At a little over 3 miles is another cut (1003), 60 yards long. The east half shows a green and black gneiss which is fairly basic, containing much hornblende and considerable augite and magnetite, with also a little bronzite. Nearly half the feldspar is plagioclase, whose character as an acid andesin is indicated by extinctions of 10%. The rest of the feldspar is untwinned and may be orthoclase. Quartz is absent except as small inclusions in the feldspar. The dark minerals constitute some 40% of the rock. The west end of the cut shows a red, granitic gneiss. This shows a sharp boundary against the other, but the junction is parallel to the vertical foliation of both, and a thin pegmatite band intervenes. The green gneiss passes into an amphibolite gneiss near the junction, but this seems clearly a phase of the green, just as the pegmatite seems clearly a phase of the granite. The pegmatite streak sends out stringers into the amphibolite however and clearly cuts it intrusively.

Less than ¼ mile beyond is another long cut (1004) exhibiting an identical rock assemblage. Here again the green gneiss becomes black near the junction through increased amount of dark silicates, but the pegmatite is lacking, the granitic gneiss becomes distinctly finer grained near the contact and unmistakably cuts the green, sending numerous thin sheets into it along the foliation planes.

Just east of the Piercefield depot, 3 ⅜ miles from Tupper lake, are exposures in the bed of a brook (1005) of a green, very granular, shotlike gneiss, which readily crumbles on exposure. A precisely similar rock shows along the road from the depot to the village (997), associated with a very rusty, rotted amphibolite. Basic minerals make fully one third of the green gneiss, hypersthene predominating, then come augite, hornblende, much less, abundant magnetite and apatite and a little zircon. The remainder of the rock is feldspar, no quartz appearing. The feldspar is nearly all plagioclase with 8° maximum extinction, and close to oligoclase therefore. A few somewhat larger individuals are of microperthite. The rock is therefore quite like the green gneiss of the preceding cuts and differs from the syenite in the character of the feldspar.

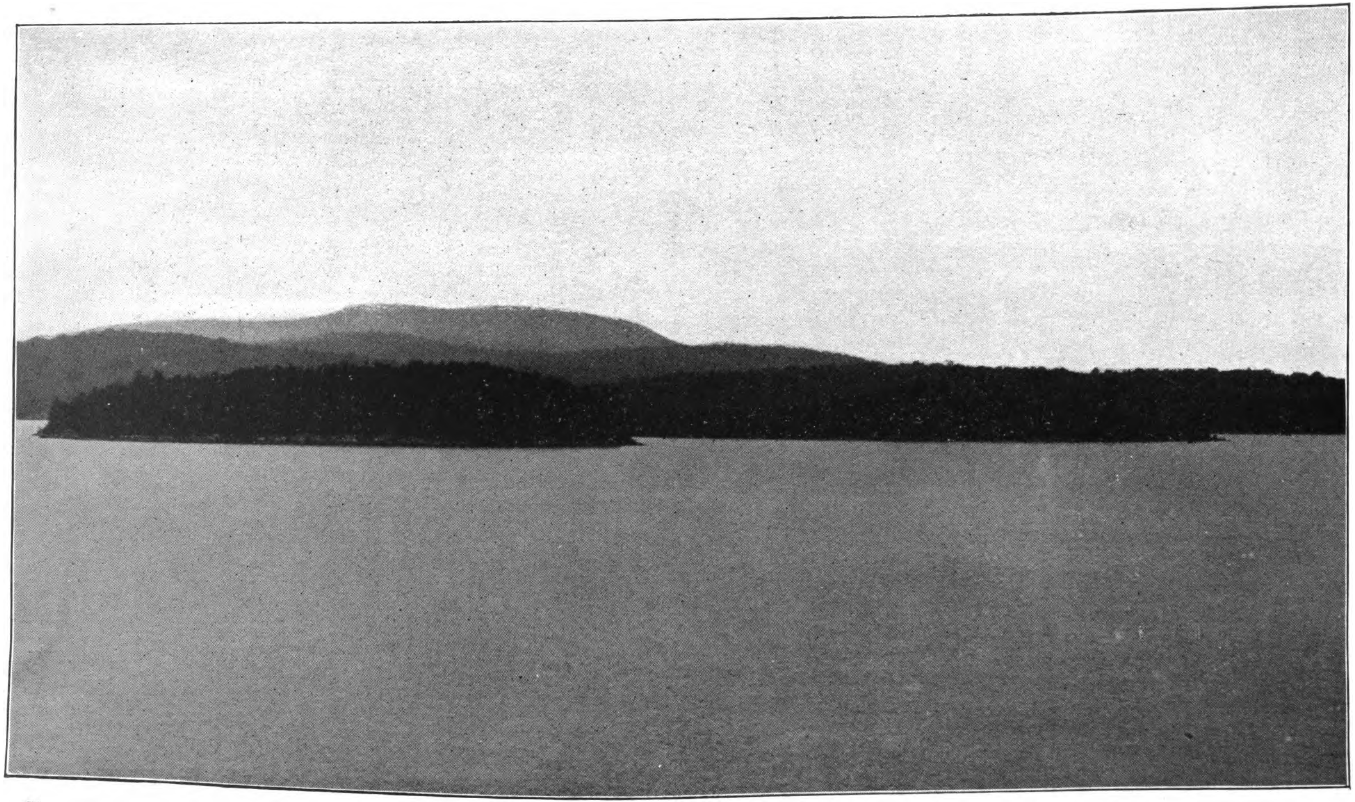
Coming into the town, a mile from the depot, repeated ledges appear of red, granular gneiss (998), composed of magnetite (much and idiomorphic), titanite (much, of the orange, pleochroic variety), augite (emerald green, pleochroic and somewhat less than the titanite in amount) feldspar and quartz. The feldspar makes some 60% of the rock and is beautifully marked microcline. Quartz constitutes 20% to 25%, much of it occurring as inclusions in the feldspar. From Piercefield on northwest to Gale's and beyond little else than red, granitic gneisses occurs.

Childwold station is 2 miles west of Piercefield. Between the two there is but one rock cut (1006), situated ¼ mile east of Childwold. This shows the same combination of fine grained, green gneiss and red, granitic gneiss found in the cuts east of Piercefield. The strike of these rocks is from n. 65 w. to n. 75 w., so that, since crossing the Raquette the railway has followed the strike of the belt. At Childwold the southerly direction is resumed, and different rocks are at once met. At ⅕ mile south of Childwold station is a considerable cut (1007) in a greenish, rudely gneissoid rock, which is a decidedly different looking rock from the green gneiss of the preceding exposures and seems certainly referable to ordinary augite syenite. It is a much firmer, more massive rock, lacks the granular look, is not evenly but very rudely foliated and is much more plainly an igneous rock. Nor is there any associated red gneiss. It also has the precise mineralogy of the augite syenite, the same augite and bronzite with their characteristic parallel growths, subordinate hornblende, the three together constituting only some 10% of the rock, which is predominantly feldspathic. The feldspar is mainly microperthite though with considerable oligoclase and some feldspar of uncertain nature. There is barely 5% of quartz. There are some amphibolitic streaks which may represent either stretched segregations or inclusions, probably the former.

East from this point and lying between it and Big Tupper lake is the large irregular mass of Arab mountain. In a trip across through the woods no rock was seen other than that which seemed clearly referable to the augite syenite, though the numerous exposures are of the unsatisfactory character usual in the woods, largely moss-covered and not furnishing fresh material. This line is parallel to and not far south from the belt of red and green gneisses along the railway, just described.

Plate 6

To face p. 150



H. P. Cushing, photo.

Looking across Tupper lake from the Moody P. O., showing two small rock islands, the low ridges of the west shore, and the east front of the Arab mountain mass in the background. All are of augite syenite.

South along the 7 miles of railway between Childwold and Horseshoe, rock cuts are frequent, and all show no other rock than quite typical augite syenite, though mostly quite thoroughly gneissoid. About Pleasant lake, 3 miles from Childwold station, exposures are very numerous, and a southerly spur of Arab mountain breaks down in tremendous cliffs of this rock to the east of the track. From this point another crosscut to Tupper lake was made, by way of Bridge Brook pond, and here also nothing but syenite was seen for the first half of the distance. Beyond, it becomes somewhat involved with granite, specially at the west end of the pond. Such granite is frequently associated with the syenite in the Tupper lake vicinity and will be again reverted to.

The last syenite seen going south along the railway (1035) was found in the woods ¼ mile west of the track and 1 mile north of Horseshoe. About Horseshoe somewhat different rocks appear, and in a crosscut through the woods from Horseshoe to the south end of Tupper lake no syenite was seen in mass. But between Childwold and Horseshoe the syenite crosses the railway in a belt 6 miles in width from north to south. Its extent farther west has not yet been determined, but it can not go far, since Smyth's work about Cranberry lake shows that it dies out before that point is reached.

Summary of section. The above detailed observations show that the augite syenite which is exposed widely about Big Tupper lake, extends solidly west through the woods to the railway, which it crosses in a belt 6 miles in width, dying out not far to the west; that to the north of it, along the Raquette river, is a belt of red and green gneisses increasing in breadth westward. The green gneisses in this belt much resemble some of the more gneissoid phases of the augite syenite, and it will be later shown that they are closely related chemically. They are moreover confined to the border zone, and only the associated granitic gneisses persist. The latter cut the green gneisses intrusively and are clearly somewhat younger. If the green gneisses have no connection with the syenite, and the whole represents an older series, it is strange that no evidence of this is forthcoming in the way of contacts or of dikes from the syenite cutting the other. The more probable explanation is thought to be that we are here dealing with a great area of eruptive granite which cuts and becomes involved with the syenite, forming a border zone. It should however be stated that the titanite gneisses shown here are somewhat unusual, generally of no great extent, and are not the usual border rocks of the syenite.

This belt of gneisses seems prolonged to the southeast as a narrow band, crossing the Raquette between Tupper lake and Raquette pond, and expanding along the shores of Big Simons pond. In this extension the titanite gneisses are not found, the rocks being granitic gneiss and certain mongrel gneisses which appear like somewhat weathered augite syenite, such as are frequent in the border zone. This band appears to separate completely the Big Tupper lake syenite mass from that found at Tupper Lake village and thence north and east. But it is the latter that sends out the dikes into, and shows gradation into the anorthosite; while the border zone under discussion might be regarded as pertaining equally to each. The village mass also, on its west side, shows a perfectly characteristic border zone, and then passes into granite, precisely as does the lake mass, though the former is in a difficult region and has not been so carefully investigated.

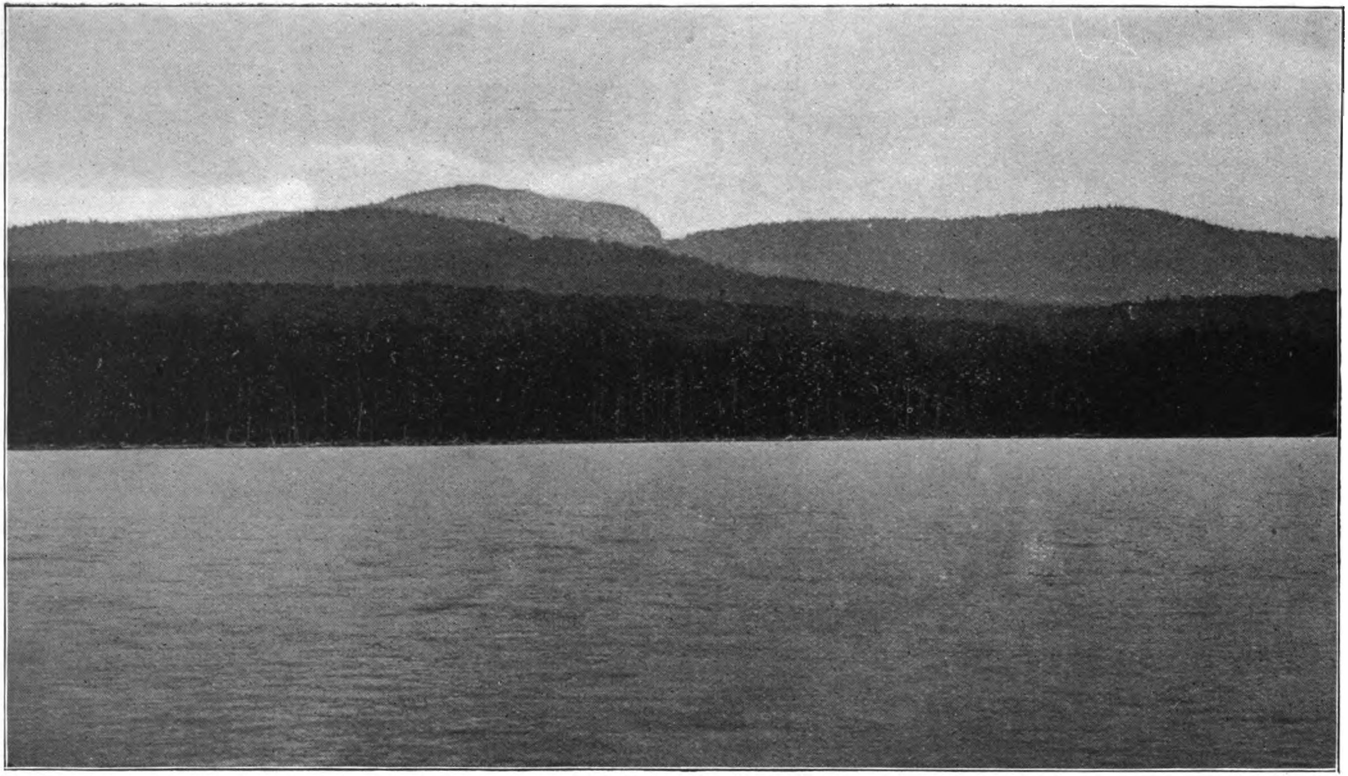
It should also be emphasized that the intervening belt under discussion here, constituted of granitic gneiss and other gneiss which is akin to the syenite, would be unhesitatingly classed in the ordinary "gneiss" division of the Adirondacks (Kemp's series 1) were the neighboring syenite not present, and emphasizes the view that the syenites are akin in origin and age. It should be further said that this series 1, as at present constituted, includes many and diverse rock types.

District between Big Tupper lake and Horseshoe pond

The shores of and the islands in Big Tupper lake are composed of augite syenite except at the extreme upper end. For the most part they are rocky, so that exposures are frequent and show well

Plate 7

To face p. r52



H. P. Cushing, photo.

Looking east from the north end of Cliff island, Big Tupper lake, showing Mt Morris with its burned summit, and its long, wooded, southeasterly spur. Except for a small area of granite the mountain is of augite syenite throughout.

the variations to which the rock is subject. This syenite area is followed to the south by a belt of syenite involved with granite, which runs down the west shore of the lake for some little distance. On that shore, just opposite the south end of County Line island, is an exposure consisting mainly of red granite, but with some green syenite gneiss also. The granite is of the coarse type, with long quartz spindles and wholly free from dark silicates, which is often found associated with the syenite. Here it distinctly cuts the syenite intrusively, the syenite being present only in wedge shaped horses and smaller fragments surrounded by the granite. Furthermore, it maintains its usual structure and grain throughout, whereas the granite becomes quite fine grained in a narrow zone about it, whose breadth is rudely proportional to the size of the inclusions, and varies from a few inches up to 2 feet.

Farther south along the west shore the rock becomes less typical syenite and much cut out by various granitic gneisses. This same sort of a zone seems to surround the syenite on all sides. Other rocks begin to appear in it, notably the spindle granite and its finer grained contact phase. The syenite itself becomes more acid and grades into an augite granite which has the structure and aspect of the syenite rather than that of the spindle granite. Considerable masses of syenite often occur in this border zone. For example, in ascending Mount Morris from Moody, the syenite is left behind as the summit is neared and only granite appears, followed again by syenite at the summit. Thence south into Litchfield park, the syenite comes in again, unbroken syenite occurring all around Lake Madeline, running into the mixed rocks on all sides.

In the woods between the upper end of Tupper lake and Horseshoe station, a distance of some 5 miles, the few exposures found for the first half of the distance are of the mongrel gneiss, which, while having considerable resemblance to the augite syenite, is not typical for that rock and is considerably involved with granitic gneiss. On the south shore of the pond a gneiss of wholly different relationships appears in a narrow belt which extends south from the pond to Bog river and possibly beyond. The outcrops (1022 and 1023) are of a fine grained, easily rotting, black and white gneiss, which is fairly basic and full of coarse, more acid, pegmatitic streaks. It is one of the hornblende gneisses which crop up in all situations in the Adirondacks, but rather suggests some of the Grenville gneisses.

A little beyond, ⅕ mile east of Horseshoe station, on Mr Low's narrow gage railway, is a rock cut (1024) in a thoroughly gneissoid, granitic rock made up of microperthitic feldspar (some 60%), quartz (25%) and hornblende and magnetite. The rock is medium coarse, tends toward a granitic, rather than a granulitic structure, and, while differing somewhat from the usual run of the granite which is associated with the syenite, is likely referable to that.

On the New York Central and Hudson River railroad, ¼ mile south of Horseshoe station, is a rock cut (1025) in a coarse red gneiss, quite similar to the last except for being less gneissoid, so that strictly it is a slightly foliated granite. For a mile north of Horseshoe there are no rock cuts, though there are several deep cuts in the heavy drift there. In these are many boulders of black and white gneiss similar to the rock south of the pond (1022). These boulders often show graphite scales and tend to emphasize the reference of that rock to the Grenville series.

Southwest from the station, on the narrow gage, a rock cut is met at a distance of ¼ mile. Here is a hornblende gneiss of varying grain, with crushed and drawn-out augen of white feldspar. The track here runs about with the strike (n. 55° e.), and on the north side of the cut is a much more acid, almost granitic gneiss, which is plainly interbanded with the other. Each is quite like the corresponding type of the previous rocks and indicates that there is here a belt of prevailing acid gneiss, interblended with hornblende gneisses which sometimes approach amphibolites, neither rock closely resembling any of the syenite phases. The point to be emphasized is that this is a narrow band, hemmed in by the igneous syenites and granites on both sides, and with the syenite also blocking its course to the northeast along the strike, at no great distance.

On the narrow gage, 1 mile from the station, is a cut in a reddish green, coarse rock (1044), with numerous feldspar augen and with only a very rudely gneissoid structure, whose color is intermediate between the usual green of the syenite and the red of the granite, and which is quite typical of the augite granite into which the syenite is elsewhere found grading. 1½ miles farther, a tremendous cliff of a red, hornblende granite (1040) rises close by the track, the rock being more gneissoid than the previous, but strongly resembling much of the granite which is found involved with the syenite in the border zone. And ⅘ mile to the north, just west of Little Pine pond, is another great vertical cliff (1041) some 50 feet high, of a red granitic gneiss like the last. Here, however, it is associated with low ridges of a somewhat weathered, brown and greenish brown rock, which is certainly referable to the augite syenite. The granite is likely the later granite, though no contact was seen.

Just north of these exposures, along the road from the station to Lake Marian, outcrops of either syenite or granite, both the granitic phase of the syenite and the later granite being present, occur with more or less frequency for the first 3 miles from the depot. Then the rock changes to interbanded red gneisses and amphibolites, similar to those seen about Horseshoe pond. About Lake Marian is a mass of very interesting rocks. Along the north shore are very basic, easily disintegrating, schistose rocks, some of which are slightly feldspathic, but most of which are wholly made up of a light green diopside, colorless in thin section, and a light brown mica which is in all probability phlogopite. Both these minerals are quite characteristic of the Grenville rocks, and, though no limestone was seen, these rocks are unhesitatingly referred to that series. With these are involved red and black, and black and white banded gneisses. The former hold much orange colored titanite along with biotite, hornblende and feldspar, which is in great part microcline. But quartz is practically absent, though customarily present in large amount in gneisses of this mineralogy. The black and white gneisses also hold considerable titanite, but of higher color and largely found as rims around the magnetite. They further consist of biotite and hornblende, some 20% of quartz, and white feldspars, largely andesin, since five fragments in the slide which are properly cut give equal extinctions of from 11° to 20° on opposite sides of the albite twinning plane. The remaining feldspar would seem to be anorthoclase, though this is not certain. These rocks are quite like those associated with the magnetites at Hammondville, Essex co., and it is of interest that here also a considerable belt of lean magnetite is associated with the black and white gneiss, and close to the belt of very coarse, basic pegmatite, largely composed of coarse hornblende, with plagioclase, titanite and magnetite in addition, and apparently a pegmatitic development of the black and white gneiss. This ore belt occurs on both sides of the lake and was traced for more than a mile. It may extend much farther. In places, possibly everywhere, the rock at the contact with the ore is a peculiar granulite of somewhat rusty appearance, and containing some 60% of emerald green pyroxene, orange colored titanite, and abundant orange brown garnet whose shade is very like the deeper color of the pleochroic titanite. The remaining minerals are evenly granular quartz and feldspar, which are exceedingly difficult to distinguish, since the feldspar is very fresh and wholly unmarked. The whole makes a strikingly beautiful combination in thin section. Beyond this belt the granitic gneisses appear again. It is difficult to tell whether the ore and associated rocks should be regarded as members of the adjacent Grenville series or not, though a strong impression is produced that such is the case.

Summary of section. The preceding details show that on the east, south and west the Tupper lake syenite is bordered by a zone of mixed rocks, consisting of very gneissoid syenite involved with granitic gneiss. On the one hand, the syenite is found grading into a granite which bears a strong external resemblance to it and often contains the same augite, the passage from one to the other being wholly unmistakable. On the other hand, there is abundance of a granite, often very gneissoid, which shows always intrusive contacts against the syenite when contacts are exposed, and which is therefore later, but at the same time would seem to represent an important member of the eruptive series that makes up the heart of the Adirondacks. As one recedes from the main syenite mass, the syenite content of the border zone becomes continually smaller and eventually disappears, while the granitic gneiss spreads away to the south and west. But even well away from the main syenite mass, small bodies of syenite are frequently met which are seldom accommodating enough to disclose their relationships to the surrounding granite. Patches of the Grenville rocks, or of doubtful gneisses which are likely of Grenville affiliations, are found here and there, but such patches occur also in the midst of the syenites and anorthosites. This border zone differs slightly from that on the north, and the evidence that we are dealing with a mixed belt of syenite and granite lying between a syenite mass and a granite mass, seems stronger than on the north, though it appears to be also the case there, the rocks just about Piercefield being of somewhat doubtful association.

GENERAL CONCLUSIONS

The above recorded observations seem to the writer to prove in some cases, and to strongly indicate in others:

1 that the Adirondack anorthosite is cut intrusively by an augite syenite which is therefore younger;

2 that, while the larger part of the augite syenite of the Adirondacks is in such situation with respect to the anorthosite as to render impossible any determinations of relative age, its general character is so uniform throughout that it is exceedingly probable that it is all of the same approximate age and consists of intrusions from the same source;

3 that at their borders these syenites pass over into granites, part of which at least cut the syenite eruptively and are therefore younger;

4 that the syenite grades into granite on the one hand and into gabbro diorite on the other, and apparently into anorthosite as well;

5 that the three together, anorthosite, syenite and granite, form a great eruptive complex in the heart of the Adirondack region, and that all are younger than the (in part at least) sedimentary Grenville rocks.

The writer was at first disposed to take a different view from that given above, thinking that the probable explanation of the phenomena was the presence of augite syenite of two different ages in the region, the one younger and the other older than the anorthosite, the last to be classed in the general "gneiss" series of the Adirondacks. While that may yet prove the true explanation, the probabilities seem to favor the one outlined above, and some discussion of the subject seems desirable, since the determination of the truth or falsity of either view is a matter of much importance in Adirondack geology.

Classification of the Adirondack pre-Cambrian

The classification of the pre-Cambrian rocks which we have been tentatively using in the Adirondacks is one proposed some 10 years ago by Kemp. Excluding certain dikes, the rocks were divided into three groups.

Series 1 was defined as a great group of gneisses of diverse kinds and of somewhat uncertain origin, though likely in great part igneous.

Series 2 comprised the crystalline limestones and associated quartzose, sillimanite and graphitic gneisses, all representing metamorphosed clastics, and closely interbanded with other, notably basic, gneisses which are probably igneous but can not be separated from the main group.

Lest it should be imagined that this order carried any implication as to the relative ages of the two groups, it should be stated that the grouping is a wholly lithologic one, and that Kemp has constantly maintained that there was no evidence that any of the rocks included in series 1 were older than the rocks in series 2, though admitting that older rocks might be represented.[1]

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[1] Kemp, J. F. N. Y. state geol. 13th an. rep't. 1893. 1 : 448.

Series 3 was constituted to include the rocks of the gabbro group, both anorthosite and gabbro. Though, again, the subdivision is a lithologic one, Kemp held that these rocks were later than those of both the other series, and the time element was made of importance in the characterization of the group. Further, at the time the classification was proposed these gabbro rocks were the only ones known to be later than the rocks of series 1 and 2 in the Adirondack pre-Cambrian.

This classification was proposed as a working hypothesis simply, and has been of the greatest service in all subsequent work.

All the Adirondack pre-Potsdam rocks, excluding certain dikes which are not metamorphosed, but which the writer has shown to have preceded the Potsdam, are included in these three series. Regarding the matter from the lithologic standpoint, the effect has been that we have classified everything in series 1 which could not be unmistakably shown to be clastic, and hence to belong to series 2, or to be a gabbroic rock and hence a member of series 3. As a result, series 1 has come to include a great variety of rocks, likely of very diverse age, and we all recognize that the great problem of Adirondack pre-Cambrian geology is the proper discrimination and separation of these diverse elements.

Since, however, the gabbro rocks are distinguished from those of the remaining series, not only from the lithologic standpoint, but also because they are clearly of eruptive origin and because they are younger, it would seem philosophical to enlarge that group in order that it may contain not alone gabbros, but also all rocks which can be shown to be of igneous origin and to be akin in age to the gabbros. This is in fact the position taken by Kemp, the age difference being deemed of more importance than the lithologic.

In the writer's judgment a large (it is likely the larger) part of the rocks which have heretofore been classified with series 1 can be shown to be eruptives and to be in all probability as young as the anorthosite. So probable does this seem that it is quite justifiable to point out the effect from the classification standpoint, and to urge the consideration of a modified classification as an alternative working hypothesis.

Recent work of Kemp and Smyth

At this writing the latest published reports on the Adirondack work embody the results reached up to the close of the field work of 1897 only; the more recent results not being available, unfortunately, for comparative purposes, because unpublished. This is more specially true of Prof. Kemp's work, a recent consultation with Prof. Smyth having made him and the writer familiar with each other's results. But in the 17th annual report of the state geologist appear papers of great importance by both Kemp and Smyth, which have bearing on the subject under discussion.

Kemp's report deals mainly with the extreme southeast portion of the region. He shows the presence of considerable bodies of augite syenite which he classes with the general group of gneisses, series 1, as the "Whitehall type" of gneiss. He classes them thus, since they are gneissoid and involved with other gneisses, and since no opportunity was afforded for determining their relations to the anorthosite, that being absent in the district. He remarks also the abundance of crystalline limestone and the various gneisses, in large part of probable sedimentary origin, which are everywhere associated with it. He also shows that much of a granitic rock, sometimes quite massive but more often gneissoid, occurs, and describes it as the "Horicon type" of the gneiss group (series 1). The writer is disposed to correlate these granitic rocks with the granites described in this paper as associated with the syenite in the Tupper lake region, but, as he has not seen the specimens, the reference is, of course, merely tentative. Kemp does not seem to have come across any exposures which would throw light on the question of the relations of the "Whitehall" gneiss (augite syenite) to the crystalline limestones on the one hand, or to the granitic rocks of the "Horicon type" on the other; at least no reference to these relations has been noted in a careful reading of the paper. On p. 540, in describing the rock succession at the graphite mine in Hague, Kemp mentions an acid, titanite gneiss as forming the lowest rock seen, and makes the acute suggestion that it probably belongs in the general eruptive series with the Whitehall augite syenite gneiss. This is precisely the same gneiss as that described from and about Piercefield in the present report. It is also the same gneiss as that about Lake Marian, where it is associated with a magnetite ore body and with supposed Grenville rocks. Though the writer is in doubt as to its precise relations, his inclination is to refer it to the general eruptive series, as Kemp does.

To summarize, Kemp reports large bodies of syenite and granite, mostly gneissoid, whose eruptive origin is distinctly stated, which are, by implication at least, younger than the Grenville series, but whose relationship to the anorthosite there is no opportunity for determining.

Smyth's report deals largely with an area of augite syenite in the western Adirondacks, the Diana-Pitcairn area, in which most interesting and important observations were made and recorded. In this area again, however, the absence of anorthosite precludes any determination of the relations of the two eruptives. But, on the other hand, the rock, variable here as elsewhere, is shown to have an important gabbro facies, and to pass locally into a gabbro.

The evidence detailed in the report shows in the clearest manner that the syenite cuts the Grenville rocks irruptively and is therefore younger, the widespread character of the Grenville on the northern border of the syenite giving exceptional opportunity for such determination. It also shows that on the south the syenite boundary is not clearly defined, but that it apparently passes over into a granitic gneiss, and Smyth had previously shown a definite transition of the sort, west of Natural Bridge in Jefferson county.[1] Farther to the south, he shows the presence of a different granite, usually gneissoid, which he is in doubt whether to regard as a derivation product of the syenite or as representing a separate intrusion, but which in either case emphasizes their close relationship. He also remarks the wide distribution of such granitic gneisses in the southwest Adirondacks.

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[1] Geol. soc. Am. Bul. 6 : 282-83.

The above observations fall exactly in line with those detailed in the present report. The augite syenite is found grading into a granite on the one hand; on the other, another granite is found, and the writer's observations would indicate that this is later and cuts the syenite intrusively. This is certainly true of a granite which can not be distinguished from the main mass of the rock. That the syenite is markedly younger than the Grenville rocks is also shown, and to greater perfection than in any other locality yet known in the Adirondacks.

Relationship of the syenite and granite to anorthosite

It would seem that there is substantial agreement between Prof. Kemp and Prof. Smyth and the writer, that there are large masses of syenitic and granitic gneisses in the Adirondacks, which are of igneous origin and younger than the Grenville rocks. But, so far as the writer is aware, no observations bearing on the relative age of the anorthosite as compared with the syenite and granite have been put on record, aside from those from the localities mentioned in this report. Here a locality has been described in which there is an apparent transition from anorthosite to augite syenite, though the outcrops are not sufficiently numerous to permit of certainty in the matter; another locality has been described, where augite syenite appears in considerable force invading anorthosite irruptively, and yet others where augite syenite dikes cut the anorthosite. There are also occasional granite dikes in the same rock. But the reverse phenomena have not been noted. The anorthosites cut the Grenville rocks irruptively, but there is no evidence either in the shape of contacts or of dikes to show that they are later than the syenite. The evidence is conclusive that augite syenite is present in the Adirondacks, which is closely related to the anorthosite, but which is somewhat younger.

While it has not been, and for the most part can not be shown, that the different augite syenite areas in the region are all of approximately the same age, there is, so far as the writer knows, absolutely no evidence of difference in age, and the structural, mineralogic and chemical characters of the rock in the different areas agree so closely as to afford strong presumption of their essential unity. Granting the unity of the rock, it must then be all classed with the anorthosite as a member of series 3 of Kemp's classification. The granites also, the one due to variation in the syenite mass, the other of somewhat later origin, must be included in the same series, which thus comes to include a great group of eruptive rocks ranging from acid granites, through syenite and anorthosite, to quite basic gabbros.

One objection to the above view which has often impressed itself on the writer is that the syenites and granites are more frequently and more markedly gneissoid than are the anorthosites, thus presenting the appearance of having experienced more excessive metamorphism than has fallen to the lot of the anorthosite, and therefore implying a greater age. But it is believed that this difficulty is more apparent than real, and likely is due to the peculiar character of the anorthosite magma. The great deficiency of iron and magnesia in this, which gives the rock its character as a purely feldspathic one with nearly total freedom from dark silicates, is probably responsible for its unusual coarseness of crystallization, and prevents much recrystallization as a result of metamorphism, at least recrystallization can only give rise to more feldspar. All three rocks anorthosite, syenite and granite, show much variation from place to place, being here quite massive and there well foliated, and the more massive syenites and granites show clearly that they never possessed any approximation to the very coarsely crystalline character of the anorthosite. Therefore they would granulate more readily and would show small, rather than large augen. Whenever the anorthosite shows any tendency toward gabbro, dark silicates appearing in any amount, the grain becomes less coarse, foliation appears and recrystallization also, notably shown by the abundance of garnet. The more purely feldspathic syenites also are apt to be coarser than those in which the iron and magnesia percentages are higher.

The eruptive core of the Adirondacks

It has been shown in the preceding pages that the anorthosite tends to grade into a more gabbroic rock at its borders, becoming at the same time much more gneissoid, and it is also the fact that it fades out into the neighboring rocks through transition phases, precisely as the syenite does. The Franklin county anorthosite, the only large mass with which the writer is personally familiar, passes at the south and southwest into a more and more gneissoid rock, with constantly fewer and smaller labradorite augen, which finally disappear, and the rock would not be taken to have even a remote connection with anorthosite by an observer coming on it from the opposite direction. Kemp reports similar facts from Essex county. These border zones of the anorthosite deserve more attention than they have yet received. In the writer's district they have not yet been met with under sufficiently favorable auspices to encourage detailed work. All the exposures seen show the rock much rotted and altered.

The gabbros (hyperites) illustrate the same thing. They frequently show a more or less massive core, from which they pass into gneissoid gabbro diorites and amphibolites on all sides, and these may become involved and interbanded with other rocks, so that they can not be sharply separated in mapping.

Moreover they have a wide range in the Adirondacks, far beyond that of the anorthosite, and thus negative any argument seeking to separate the syenite from the anorthosite because of its much wider range. The same reasoning would also separate the gabbros, yet these are clearly later than the anorthosite. It is therefore thought that the apparently less metamorphosed character of the anorthosite is merely an apparent difference, likely a result of its peculiar chemical composition.

But, if it be granted that these rocks, ranging from granite to gabbro, are all members of a great eruptive series of which the anorthosite would seem to be the oldest member, interesting consequences follow in regard to the distribution of the eruptives, and in regard to the content of series 1 if these be abstracted.

As a result of reconnaissance work in 1890, Van Hise came to the conclusion that the Adirondack pre-Cambrian comprises "a core of eruptive basic rock, which has upthrust and intruded itself within the gneissic series. Because of the character of the gneissic series, containing quartz schist, graphite schist, and crystalline limestone, including graphite, it is regarded as having been originally clastic. Its present crystalline character and quaquaversal arrangement is doubtless due to the intrusion of the gabbro. . . The lowest coarse grained gneiss, inferior to the limestone, perhaps belongs to a still earlier series, but this is a point upon which closer studies are needed."[1]

During the progress of the later Adirondack work we have been finding considerable fault with this summary of Van Hise's. Most certainly, if the eruptive core be limited to the gabbro rocks, the statement is wide of the mark, nor is the assertion of a quaquaversal arrangement of the gneisses found to accord with our observations on dip and strike. But, if the syenite and granite be included in the eruptive series in addition to the gabbro rocks, then the statement in respect to the eruptive core comes much nearer to representing the real state of things; though, since the eruptives are themselves heavily metamorphosed, their invasion can not be regarded as the sole, or perhaps not even as the main cause of the crystalline character of the gneisses. If they be included, then the great central mass of the Adirondacks does consist of an eruptive complex, anorthosite on the east and north, syenite and granite on the south, west and north, eruptives which have invaded the gneisses from beneath. Kemp, in a recent valuable paper on pre-Cambrian sediments in the Adirondacks,[2] has emphasized the massing of the limestones and clastic gneisses on the southeast and northwest. While in a general way this is true, small outcrops of these rocks are more numerous in the heart of the region than the published data at Kemp's disposal when his paper was written led him to believe. These patches are of small extent and occur wholly surrounded by, and resting on the eruptives. In the writer's judgment, many more will be found when the interior region is more carefully gone over than has hitherto been possible, and there must be others wholly concealed beneath drift and ordinary forest covering; but, as it is, they are sufficiently numerous, and of sufficiently scattered distribution, to indicate that the clastics formerly spread over the entire region, and have been almost completely removed from the interior by erosion. A quite possible explanation of the difference in conditions between the heart of the region and the border, between prevailing eruptives holding scattered patches of the clastic gneisses and much more abundant clastics with occasional eruptive knobs, is that erosion has cut more deeply in the heart of the region, that it has experienced greater uplift and therefore greater wear than the border, so that the conditions which prevail at the surface in the former are yet buried at some depth below it in the latter. The occurrence of augite syenite forming the pre-Cambrian outlier at Little Falls in the Mohawk valley shows that the eruptives pass under the Paleozoic cover at the extreme border along with the clastic gneisses, and that therefore the invasion of the clastics by the eruptives from beneath was widespread and not limited simply to the heart of the Adirondacks.

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[1] Van Hise, C. R. U. S. geol. sur. Bul. 86: 398-99.

[2] Science. New ser. 12: 81-98.

If the syenite and granite be transferred from series 1 to series 3, what remains of the former? It certainly is vastly diminished in importance and, instead of being the most extensive of the Adirondack formations, comes to be subsidiary to series 3. There is however in the region a considerable body of gneiss, for the most part of border distribution, which seems not to have any connection with the eruptives of series 3. Though these gneisses seem to be in part of igneous origin, such origin for another part is open to considerable doubt. Such gneisses form most of the pre-Cambrian area of Clinton county and the border of Franklin and eastern St Lawrence counties, territory over which they are singularly free from admixture with undoubted Grenville rocks, small patches of which do, however, occur. Instead of having a massive character and wide distribution, with gradation from one rock to another, they nearly always show at least a rude banding, at least two sorts of gneiss occurring in nearly every exposure, sometimes in rapid alternation, sometimes in thicker bands. The two commoner mixtures are of a red, granitic gneiss with a hornblende gneiss, or of a somewhat different, red, acid gneiss with gray, granulitic bands, usually of pyroxene granulite. In the former case both rocks seem igneous and the granitic gneiss cuts the other, but usually it has injected a multitude of thin sheets of granite along the foliation planes of the other rock, and the whole has been drawn out so as to produce a distinctly banded appearance. The other rocks are of uncertain origin and nature. Other sorts of gneiss also occur. Such rocks occur in more or less abundance all about the border of the Adirondack region, as well as in patches in its heart. And the same, or at least very similar rocks are found associated with, apparently often interbanded with, the limestones and clastic gneisses of series 2. It would appear that, in so far as they may be clastic, they belong to, and should be classed with, that series. In so far as they may be igneous, they seem in the majority of cases to be later than the clastics, though intimately interwoven with them and much earlier than the main eruptive series. If there are any rocks in the region which are older than those of series 2, they are to be found among these gneisses, but none have yet been definitely shown to be older. But there is, as yet, no evidence of any sort concerning the age of much of this gneiss. In the writer's judgment, a considerable part is to be classed with the Grenville rocks, series 2, mainly consisting of closely contemporaneous igneous rocks. It is by no means improbable that all should be so classed, and that the Adirondack pre-Cambrian can all be placed under Kemp's series 2 and 3. But, whether this be ultimately proven to be the case or not, and if the expansion of series 3 here urged be accepted, there will still remain a considerable body of gneiss for which a separate subdivision is a convenience, if not a necessity, in our present state of ignorance. The writer simply wishes to urge the other point of view as a possible one, to be used as a working hypothesis in further investigation in the region, and to record his belief that most, if not all of the Adirondack pre-Cambrian can be included in series 2 and 3 provided the former be expanded so as to include igneous rocks which were contemporary with, or followed closely on the deposition of the clastics, and which are older than the eruptives of series 3. While such subdivision wholly fails to account for the floor on which the clastic rocks were deposited, this floor is not to be discovered at present; there still remains the possibility that it may be represented by gneisses such as those of Clinton county.

Order of succession of the Adirondack eruptives

In a region where the general rock relations were not confused by severe metamorphism, such evidence as that adduced in this paper would suffice to establish the order of succession of the eruptives as first anorthosite, followed by syenite, granite and lastly gabbro. Much later came diabase and syenite porphyry dikes, though these are still pre-Potsdam in age. There are other eruptives besides the four most prominent ones just mentioned, but only in subordinate amount.

CHEMICAL ANALYSES AND DISCUSSION

	1	2	3	4	5	6	7
SiO_2	44.77	47.42	51.62	54.47	54.62	54.38	57
Al_2O_3	12.46	17.34	24.45	26.45	26.5	20.53	16.01
Fe_2O_3	4.63	4.91	1.65	1.3	.75	2.78	10.3
FeO	12.99	10.22	5.3	.66	.56	5.5	
MgO	5.34	5.21	1.21	.69	.74	1.99	1.62
CaO	10.2	8.09	9.97	10.8	9.88	5.39	6.2
Na_2O	2.47	3.48	3.49	4.37	4.5	5.2	4.35
K_2O	.95	1.89	1.27	.92	1.23	3.4	3.53
H_2O	.6	1.13	.72	.53	.91	.5	.15
CO_2	.37	......	......	......	......	......	......
TiO_2	5.26	3.6	......	......	......	.09	......
P_2O_5	.28	.06	.01	......	......	.15	......
Cl	......	.21	......	......	......	.03	......
F	......	......	......	......	......	.03	......
S	.26	......	......	......	......	......	......
MnO	.17	.06	.1	......	......	.01	......
BaO	trace	.04	......	......	......	.16	......
Total	100.75	100.01	99.79	100.19	99.7	100.03	99.16
Sp. gr	3.09		2.798	2.72	2.7	2.7	

	8	9	10	11	12	13	14
SiO_2	59.7	61.01	60.47	63.45	65.65	66.72	68.5
Al_2O_3	19.52	15.36	16.36	18.38	16.84	16.15	14.69
Fe_2O_3	1.16	10.75	.8	.42	4.01	3.42	1.34
FeO	5.65		8.76	3.56			3.25
MgO	.78	.78	1.31	.35	.13	.73	.26
CaO	3.36	4.05	2.94	3.06	2.47	2.3	2.2
Na_2O	5.31	3.68	4.65	5.06	5.27	4.36	3.5
Ka_2O	4.14	3.9	4.71	5.15	5.04	5.66	5.9
H_2O	.52	.49	.09	.3	.3	.77	.4
TiO_2	......	......	......	.07	......	......	......
P_2O_5	......	......	......	......	......	......	.03
MnO	.09	.08	.12	trace	......	.07	.1
BaO	......	......	......	.13	......	......	.05
Total	100.23	100.1	100.21	99.73	99.71	100.18	100.22
Sp. gr	2.674		2.82	2.72			

Molecular ratios

	3	4	6	8	9	11	13	14
SiO_2	.8603	.9078	.9063	.995	1.0168	1.0575	1.112	1.1417
Al_2O_3	.2397	.2593	.2004	.1912	.1506	.1795	.1584	.144
Fe_2O_3	.0103	.0081	.0174	.0072	.0216	.0026	......	.008
FeO	.0736	.0092	.0764	.0785	.1014	.0494	.0475	.0451
MgO	.0302	.0172	.0497	.0195	.0195	.0087	.0182	.0065
CaO	.178	.1929	.0963	.06	.0723	.0523	.0411	.0393
Na_2O	.0563	.0705	.0839	.0856	.0594	.0816	.0703	.0565
K_2O	.0135	.0097	.0357	.0439	.414	.0547	.0601	.0626

1 Norite, wall rock of titaniferous magnetite deposit, Lincoln pond, Elizabethtown, Essex co. Description by J. F. Kemp, analysis by W. F. Hillebrand, U. S. geol. sur. 19th an. rep't. pt 3, p. 407. 1899.

2 Gabbro (hyperite), dike near Nicholville, Hopkinton, St Lawrence co. Brief mention by H. P. Cushing. N. Y. state geol. 16th an. rep't. 1896. p. 22. E. W. Morley analyst.

3 Anorthosite gabbro, Carnes's quarry, Altona, Clinton co. Description by H. P. Cushing, analysis by E. W. Morley. N. Y. state geol. 19th an. rep't. p. r58.

4 Anorthosite, summit of Mt Marcy, Keene, Essex co. A. R. Leeds analyst. N. Y. state mus. 30th an. rep't. p. 92.

5 Anorthosite, Keene township, Essex co. (precise locality not given). A. R. Leeds analyst. N. Y. state mus. 30th an. rep't.

6 Anorthosite showing transition to augite syenite (905), cut by N. Y. C. & H. R. R. R. nearly 5 miles north of Tupper Lake Junction, Altamont, Franklin co. E. W. Morley analyst.

7 Gabbro, intermediate between gabbro and augite syenite and occurring as a basic phase of the latter; from Natural Bridge, Diana, Lewis co. Description and analysis by C. H. Smyth jr. Geol. soc. Am. Bul. 6:274.

8 Augite syenite (935) from the great intrusion into anorthosite, road from Tupper lake to Wawbeek, ¼ mile east of Halfway brook, which marks the line between townships 22 and 23, Franklin co. E. W. Morley analyst.

9 Augite syenite, cut by N. Y. C. & H. R. R. R. 3½ miles north of Tupper Lake Junction (906) and 1 mile from the first anorthosite outcrops, the latter being of the transition type of 905, analysis 6; Altamont, Franklin co. E. W. Morley analyst.

10 Gneiss, referred somewhat doubtfully to augite syenite; occurs involved with a later granitic gneiss in the border zone of the augite syenite; from cut by N. Y. C. & H. R. R. R. between Piercefield and Childwold, and ⅛ mile from the latter (1006); Hopkinton, St Lawrence co. E. W. Morley analyst.

11 Augite syenite, Loon lake, Franklin co., typical. Description by H. P. Cushing, analysis by E. W. Morley. Geol. soc. Am. Bul. 10:177-92.

12 Augite syenite, near Harrisville, Diana, Lewis co.; the gabbroic rock, analysis 7, is a differentiation phase of this syenite. Description and analysis by C. H. Smyth jr. Geol. soc. Am. Bul. 6:271-74; and N. Y. state geol. 17th an. rep't 1897. p. 471-86.

13 Augite syenite, Little Falls, Herkimer co. Description in the paper on the pre-Cambrian rocks at Little Falls which accompanies this report. E. W. Morley analyst.

14 Quartz augite syenite, from border zone and accompanied by granite, cut by N. Y. & Ottawa R. R. 2½ miles south of Willis pond, Altamont, Franklin co. E. W. Morley analyst.

The writer wishes to express his great indebtedness to Prof. Morley for his hearty cooperation. Part of the above analyses were made out of pure goodwill for the writer; part by order of the New York state museum.

Discussion

The gabbros are the most basic rocks of the Adirondack eruptive core, except for their own local, iron rich differentiations which give rise to the titaniferous magnetite ore deposits. The two analyses, 1 and 2, represent well their general composition and the usual limits of their variation.

Unfortunately, with the exception of analysis 3, no analyses are available of the transition rocks between the gabbros and the anorthosites, such transition rocks occurring at the borders of the main anorthosite bodies as well as in smaller, separate masses, though the general differentiation of the gabbro and anorthosite must be regarded as having taken place below, in the parent magma of both. The smaller anorthosite bodies, such as those near Keeseville and on Rand hill in Clinton county, the latter furnishing the rock whose analyses appears in column 3, are very markedly gabbroic. The analysis, however, shows a rock which, in its high alumina and rather low iron and magnesia, is much closer to anorthosite than to gabbro. It, nevertheless, represents an intermediate stage in every single constituent. It was chosen for analysis because of its freshness and in spite of the fact that it appeared to be the most anorthositic portion of the Rand hill body and therefore not a fair representative of its general character. The main rock is a more strictly intermediate one, and the same thing is true of the Keeseville rock and of much of the border of the great anorthosite mass of Franklin county.

As close a calculation as can be made of the mineral composition of the anorthosite gabbro of analysis 3, without analysis of the component minerals, indicate some 70% of feldspar, made up of orthoclase 7.5%, albite 29.75% and anorthite 32%. In addition there are 11.75% of garnet, 7% of augite, 4% of hornblende, 2.5% of magnetite and 5% of quartz. The free quartz is specially noteworthy in so basic a rock, is usually to be found in the anorthosite gabbro of the region, and recalls the quartz norites described by Kolderup as associated with anorthosite in the Ekersund-Soggendal district in Norway. For comparative purposes four of his analyses are appended.

	1	2	3	4	5
SiO_2	53.42	52.61	52.21	53.28	51.62
Al_2O_3	28.36	27.15	19.24	23.3	24.45
Fe_2O_3	1.8	4.05	10.46	7.55	1.65
FeO					5.3
MgO	.31	1.55	2.36	3.02	1.21
CaO	10.49	9.96	7.28	5.01	9.97
Na_2O	4.82	4.53	3.48	3.9	3.49
K_2O	.84	.78	1.09	1.51	1.27

1 Anorthosite (labradorit), Ogne, Norway. Kolderup analyst. Die labradorfelse des westlichen Norwegens. Bergens museums aarbog. 1896. p. 20.

2 Anorthosite norite (labradoritnorit), Ekersund. Kolderup analyst. p. 20.

3 Quartz norite, Soggendal. Kolderup analyst. p. 16.

4 Quartz norite, Theingsvaag bei Ekersund. Kolderup analyst. p. 16.

5 Anorthosite gabbro, Carnes's quarry, Rand hill.

It is to be noted that Kolderup's quartz norites are more typical for the rock than the one analyzed from the Adirondacks, that approaching anorthosite more closely and being more like his anorthosite norite in many respects. His quartz norites show 10% or more of quartz as against the 5% of the Rand hill rock. But, as has been stated, the larger part of the Rand hill rock is more quartzose than the specimen analyzed and would in all probability approach his quartz norite very closely.

The chemical differences between the anorthosite gabbro of analysis 3 and the anorthosites of 4 and 5 of the original table are slight, 3 showing diminished silica, alumina and soda, and increased iron and magnesia; they suffice however to cause a drop in the feldspar content from over 90% in the anorthosite to 70% in the anorthosite gabbro. In all these anorthositic rocks part of the potash is in the labradorite, replacing a certain amount of soda. Analyses of this feldspar always show it, and, in calculating the rock analyses, it is necessary to assume that part of the calculated orthoclase goes with the albite to form labradorite, in order to bring about agreement between the computation and the observed optical properties of the feldspar.

The rock analyzed in column 6 has the appearance of an intermediate rock in the hand specimen, the feldspar augen resembling labradorite, and being sometimes iridescent, the granular portion having the look of augite syenite. Cleavage fragments from the augen give extinctions of −5° on 001 and −19° on 010, and hence are close to labradorite, $Ab_1 An_1$. But the granular feldspar is in part microperthite, and in part an acid plagioclase. The alkali percentage is abnormally high for so basic a rock. The total bases bear a very high ratio to the silica and alumina, and the considerable alteration of the augite to a chloritic aggregate renders attempts at calculation of the mineral percentages hazardous. The rock is approximately composed of orthoclase 20%, albite 44%, anorthite 11%, magnetite 4%, and the remainder of augite and garnet in the ratio of 2 to 1, including a little hornblende, apatite and quartz, the latter only as a by-product of garnet formation. In its high alkali percentage and consequent feldspars, the rock distinctly approaches the syenites, though its silica percentage remains that of the normal anorthosite.

The gabbro of column 7 is a most interesting rock. Its occurrence with, and as a differentiation product of an augite syenite body, of which it must be regarded as a basic phase rather than as a true gabbro, and its intermediate position chemically between augite syenite and gabbro, are very suggestive. Like the intermediate rock of column 6, it departs most widely from both the syenites and the anorthosites in its magnesia percentage, the general Adirondack intrusives being abnormally low in that oxid. It occupies an intermediate position between syenite and gabbro, rather than between syenite and anorthosite, and as such is nearer syenite than gabbro chemically. Through the kindness of Prof. Smyth, the writer is in possession of a slide and specimen of this rock. The analysis gives the iron as all in the ferrous condition, but there is quite a little magnetite in the rock, and a rough calculation indicates its approximate composition to be 21% orthoclase, 36.75% albite, 13.75% anorthite, 3% magnetite and 25% augite and hornblende. The feldspar content is quite like that of the preceding rock, the augen consisting of labradorite and the granular feldspar of microperthite and acid plagioclase.

The remaining seven analyses, no. 10 excepted, are all of unmistakable syenite and gave an excellent representation of its variation. The ferrous iron percentage is mostly high, and the results of some of the analyses tend to throw doubt on the reliability of the entire series of ferrous iron determinations, and hence to greatly complicate attempts to calculate the mineral percentages. The two most clearly abnormal results are those of analyses 9 and 13. In the former case the result of the ferrous iron determination exactly equaled the total iron in the rock, yet the thin section showed considerable magnetite present, and a rough separation by means of heavy solutions and a bar magnet proved the presence of at least 5% of that mineral. In the latter case the total iron present is 3.42%, yet the ferrous iron result exceeded 5%. While only these two were on their face erroneous, others, such as nos. 10 and 11, are quite suspicious. The disturbing cause can not be pyrite, since there is so little of it present that the sulfur percentage does not in general reach .01%. It is difficult to see how carbonaceous matter other than graphite can be present, and in an igneous rock any considerable amount of graphite would be surprising. The cause of the vitiation is as yet undetected.

The only analysis so far made of the augite syenite which occurs cutting the anorthosite, analysis 8, indicates that to be somewhat more basic than the usual rock, and this seems to be true of all such syenite, so far as can be judged by the thin sections. Garnet is much more abundant than in the usual syenite, and bronzite is lacking. The analysis indicates a rock composed of 24.25% orthoclase, 44.55% albite, 5.6% anorthite, 1.7% magnetite, 5.8% garnet, 14.5% augite and 3% quartz. If the ferrous iron be too high, and this is possible, though the discrepancy can not be great in this case, the magnetite and anorthite percentages would be slightly increased and those of augite and quartz diminished. Except for a slight amount of acid plagioclase, the feldspar is all of the intergrowth types, and cleavage fragments from the crushed rock show the optical characters of anorthoclase, viz a + 9° extinction on M, with an acute bisectrix in the center of the field.

The rock used for the next analysis, 9, is from near the anorthosite boundary. Ferro-magnesian silicates are more prominent than usual, considerable hornblende, augite and garnet being present and some bronzite, all together constituting some 30% of the rock. The lower alkalis show the diminished feldspar percentage, but a calculation is rendered impossible by failure of the ferrous iron determination. On the basis of 5% of magnetite, as indicated by the separation previously mentioned, the calculation gives a silica residue amounting to 13% of free quartz, which is much too high, there being but little present. The remaining analyses require little comment aside from no. 10. No. 11 is regarded as giving the closest approximation to the mean composition of the rock, and is from the Loon lake type locality.

The pyroxenes and hornblende which these rocks contain are precisely like those in the anorthosites, strongly suggesting community of origin. The feldspars are alkali feldspars with closely corresponding soda and potash content. In the general rock garnet is a much less conspicuous feature than in the anorthosites, and is often wholly absent. This is but natural, since the garnet is not primary but has resulted from the interaction of feldspar and magnetite. It is a lime iron alumina garnet, and the necessary lime for its formation is lacking in the alkali feldspar of the syenite. A further distinction between the two rocks lies in the abundance of zircon in the syenite. It by no means rises to the dignity of an essential constituent but is much more abundant and attains a larger size than in the usual igneous rock. The syenites contain quartz almost without exception, and the amount increases toward the acid end of the series, the calculation of the analysis of column 14 showing 14% of that mineral.

Analysis 10 is of a green gneiss which occurs associated with granite and granitic gneiss near Piercefield. Its field relationships to the syenite are not plain, and the doubt about its properly belonging with them is not cleared away by the analysis, which falls slightly out of the series in its magnesia-lime ratio, and in its total magnesia. The rocks nearest it in silica percentage, 8 and 9, have this ratio, 1: 3 and 1: 3.5 respectively, as against 1:1.7 in 10. Its ratio is nearest to that of 13. On the other hand, it can be argued that its general great similarity in composition would seem to ally it closely with the syenites, and that these show a great variation in the magnesia-lime ratio, even though it approaches so near to equality in no other.

General characters of the Adirondack eruptives

The analyses in the preceding table are thought to be sufficiently numerous to furnish a very fair representation of the general characters of the Adirondack eruptives, except for the lack of analyses of the granites. The latter vary greatly, ending with very acid rocks composed almost wholly of quartz and feldspar. It is quite safe to say that they will reach 75% of silica and probably higher, and that, since their feldspar is universally microperthite, the ratio of soda to potash will remain substantially as it is in the syenites.

The gabbros and anorthosites are quite normal representatives of these groups. But in the transition rocks between these and the syenites we find low magnesia, low ratio of lime and magnesia to alkalis, and approximately equal amounts of soda and potash, and these characters continue to the end of the series. The soda-potash ratio is a slowly changing one, the potash being at first below, but eventually overhauling and passing the soda in the more acid rocks. In these respects the syenites, and probably the granites, depart somewhat from the corresponding rocks of the Ekersund-Soggendal area in Norway, which also accompany anorthosite and gabbro, and which Kolderup has so exhaustively described. In general the Adirondack syenitic rocks run higher in the alkalis and lower in lime and magnesia than the corresponding Norwegian rocks. These differences are but slight, and the general agreement between the two series is very close, but they point to a slight original difference in the character of the parent magma of the two districts. The appended analyses bring this out clearly.

	1	2	3	4	5	6
SiO_2	57	57.11	63.45	64.35	68.5	70.33
Al_2O_3	16.01	17	18.38	15.46	14.69	15.59
Fe_2O_3			.42		1.34	1.4
	10.3	12.48		7.5		
FeO			3.56		3.25	1.54
MgO	1.62	1.78	.35	.5	.26	1.3
CaO	6.2	3.99	3.06	3.58	2.2	3.05
Na_2O	4.35	3.96	5.06	3.28	3.5	4.5
K_2O	3.53	2.59	5.15	3.54	5.9	1.29
H_2O	.15	......	.3	......	.4	......
TiO_2	......	1.59	.07	1.63	......	.85
ZrO_2	......	......	......	......	MnO.1	.24
BaO	......	......	.13	......	.05	......
Total	99.16	100.5	99.73	99.84	100.22	100.09

1 Basic syenite from Natural Bridge; 7 of previous table.

2 Monzonite from Fuldland near Farsund. Description and analysis by C. F. Kolderup. Die labradorfelse (les westlichen Norwegens, Bergens museums aarbog. 1896. p. 129.

3 Augite syenite from Loon lake; 11 of previous table.

4 Banatite from Dypvik near Farsund. Die labradorfelse des westlichen Norwegens, p. 123.
5 Quartz augite syenite from near Willis pond; 14 of previous table.
6 Adamellite from Farsund. Die labradorfelse des westlichen Norwegens, p. 115.

So far as their mineralogy is concerned, the Adirondack rocks would fall without question in the monzonite group. The prevailing feldspar is microperthite in which the plagioclase molecule is constantly in excess of the orthoclase, so that they are strictly plagioclase-orthoclase rocks. The table brings out the chemical differences, which would seem mainly due to the fact that the plagioclase in the microperthite is albite in the Adirondack rocks and oligoclase in the Norwegian. Certainly the Adirondack rocks closely approach the monzonite type. They also closely approach Brögger's akerite type (quartz augite syenite) from near Christiana, and seem to occupy a position intermediate between the two. Smyth's rock from Natural Bridge, column 1 of the above table, would certainly fall within the monzonite group, notwithstanding its high lime percentage; and the rock from north of Tupper lake, column 9 of the original table, belongs also in that group lying on the border land between monzonite and banatite.[1] Because of this, it is perhaps more logical to refer all the Adirondack syenite to that group, though as a somewhat abberrant type.

It would therefore appear that in each district a very similar magma has given rise to a very similar rock series, and, it is likely, through a similar differentiation process. The order of succession of the different types can not be compared, since the Adirondack succession is uncertain in one respect. The syenite followed the anorthosite, and then came the granite, but the position of the gabbro is uncertain. It is certainly later than the anorthosite, and certain gabbroic dikes which have been found cutting the syenite lead to the impression that it is later than that, but there is some question as to the correctness of their reference to the main gabbro of the region. There may have been two periods of gabbro outflow, one earlier and the other later than the syenite.

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[1] The monzonite group was established by Brögger to contain rocks intermediate between the granite syenite group (orthoclase rocks) on the one hand, and the diorite gabbro group (plagioclase rocks) on the other; hence characterized by both orthoclase and plagioclase. Monzonite has a silica percentage between 50% and 60%, banatite between 60% and 66%, and adamellite over 66%.

A few dikes, and a few small eruptive masses, of three or four different types have been noted which are not referable to any of the great masses apparently. But as yet their relationships are obscure. All are younger than the anorthosite, and all are metamorphosed.

The last outflows from the Adirondack eruptive center consisted of diabase and of syenite porphyry, both found only in the dike form. That they are considerably younger than any of the foregoing is evidenced by their wholly unmetamorphosed condition. They are however pre-Potsdam and in all probability pre-Cambrian. The diabases are exceedingly close to the gabbros in composition. The syenite porphyries are higher in the alkalis and lower in lime the magnesia than the syenites. They have a wide range in composition but are mostly quite acid and quartzose, belonging to the nordmarkite type of Brögger. In one case the diabase has been shown to be the younger. The only considerable differences between the gabbro and diabase are to be seen in the high titanium of the former and the high magnesia of the latter. The syenite porphyries depart considerably from the syenite, as has been already pointed out. They have a very localized distribution in the Adirondacks as compared with the diabases, and similar dikes have not been noted, so far as the writer is aware, in Norway or in Canada associated with the diabase.

	1	2	3	4	5	6
SiO_2	47.42	46.73	63.45	63.02	68.5	68.96
Al_2O_3	17.34	16.66	18.38	14.87	14.69	15.25
Fe_2O_3	4.91	3.56	.42	6.53	1.34	3.28
FeO	10.22	8.45	3.56	none	3.25	none
MgO	5.21	8.12	.35	.95	.26	.2
CaO	8.09	8.03	3.06	1.12	2.2	.76
Na_2O	3.48	3.73	5.06	5.85	3.5	5.45
K_2O	1.89	1.64	5.15	5.62	5.9	5.01
H_2O	1.13	2.39	.3	1.45	.4	.91

	1	2	3	4	5	6
TiO_2	3.6	.03	.07	......	......	......
P_2O_5	.06	.39	......	......	.03	......
Cl	.21	.18	......	......	......	......
F	......	.26	......	......	......	......
Cr_2O_3	......	.06	......	......	......	......
MnO	.06	trace	trace	.46	.1	.23
BaO	.04	.04	.13	......	.05	......
Total	100.06	100.2	99.73	99.87	100.22	100.05
O=Cl & F	.05	.14				
	100.01	100.06				

1 Gabbro, Hopkinton; analysis 2 of original table.

2 Olivin diabase, very fresh, olivins not perceptibly serpentinized; Belmont township, Franklin co., near Clinton county line and 1½ miles southwest of upper end of Upper Chateaugay lake; dike 13, Franklin co.

3 Augite syenite, Loon lake; analysis 11 of original table.

4 Syenite porphyry, Rand hill, Beekmantown, Clinton co.; dike 27, Clinton co. Described in Geol. soc. Am. Bul. 9:248-50.

5 Quartz augite syenite, Willis pond; column 14 of original table.

6 Quartz syenite porphyry, Rand hill; dike 28, Clinton co. Geol. soc. Am. Bul. 9:248-50. All analyses by E. W. Morley.

NOMENCLATURE

During the last field season a trip was made into Canada for the purpose of seeing the pre-Cambrian rocks to the north of those in the Adirondacks and for making comparisons between the two areas.[1] A desire of some years standing was thus gratified. The district visited, in Hastings and Renfrew counties, Ont., is a most interesting one. As the report of Dr Adams and Dr Barlow on it has not yet appeared, any detailed comments on the geology would be manifestly out of place. The main purpose of the writer was to see the rocks included by the Canadian geologist in the Grenville series and in the fundamental gneiss, in order to determine whether either, or both, of those names could with propriety be applied to the Adirondack rocks. The region visited was nephelin syenite country, many peculiar rocks appearing which have not yet been met with in the Adirondacks, nor, so far as can be judged from their prevalent trend and the prevailing northeast strike in the western Adirondacks, are likely to be found in New York. They lie too far west, and their prolongation across the boundary lies under Lake Ontario and the Paleozoic rocks of western New York, in the writer's opinion. The Grenville limestones and associated gneisses were magnificently shown in the section visited. As has been noted by numerous observers, they are lithologically indistinguishable from the Adirondack clastics of series 2, and their field relations are the same. As in the Adirondacks, they lie in wholly separate belts or patches, which show always identical rocks lithologically, and which are therefore naturally classed together, though it is utterly impossible to demonstrate that they are contemporaneous. They are classed together because of their identity in appearance and origin, the comparative nearness of the belts to one another and the fact that they seem to represent a continuous series of deposits in a single basin. In our present state of knowledge, the giving of different names to the different belts because of the fear that they may not be absolutely contemporaneous after all, seems to the writer an absurdity. It would seem equally absurd to apply several local names to the different Adirondack belts. Yet these rocks have been carried to the St Lawrence in the Thousand Island region, on the New York side, and can be, or have been, so carried on the Canadian side; the strong probability being that outcrops on opposite sides of the national boundary are no farther apart than the average distance between belts in either district. There can be no question that, if the boundary ran south of the Adirondack region instead of north of it, the Canadian geologists would have unhesitatingly included the Adirondack rocks in the Grenville. To use the term Grenville for the Adirondack rocks brings out at once the universally remarked similarity between the two series, which is wholly lost sight of, unless specially commented on, by the application of a new name to them. There is no question in the writer's mind that the rocks of both areas were deposited in the same basin and are parts of the same great, conformable series. The writer is therefore strongly of the opinion that at present no necessity exists for a local name for the Adirondack rocks, and none will exist till the stratigraphy of the series has been so thoroughly worked out that some more refined basis of comparison is available and shows its desirability.

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[1] This trip was made in company with, and under the guidance of Dr A. E. Barlow of the geologic survey of Canada, and was made possible through the courtesy of Dr G. M. Dawson, the director of that survey, and of Dr F. J. H. Merrill, New York state geologist. To all of these gentlemen the writer wishes to express his great indebtedness.

In addition to the Grenville rocks, the pre-Cambrian of that part of Canada which lies north of the Adirondack region comprises certain gneisses of doubtful age and origin, and certain later eruptives, and the rocks of each class would seem to correspond precisely to the Adirondack rocks. In Dr F. D. Adams's report on the region north of the island of Montreal, the gneisses are largely classed as belonging with the Grenville series, though certain portions are separated as of possible earlier age and hence to be perhaps classed with the fundamental gneiss.[1] But on the map accompanying the report all appear as one formation, from which the limestone bands alone are separated and given another color, the separation being therefore a purely lithologic one. The quartzite, sillimanite and graphite gneisses of probable sedimentary origin are mapped in with the main body of uncertain gneiss, the separation of the limestone being simply as an aid in interpreting the structure of the district. The gneisses are more widespread and the later eruptives apparently less so than in the Adirondacks. Because of the impossibility of making any separation between gneisses associated with, and undoubtedly belonging to the Grenville series, and other similar gneisses which occur unmixed with Grenville rocks, and hence of doubtful association, all are mapped as of the same formation. Adams, however, states distinctly that in other parts of Canada a separation can be made between the Grenville and the fundamental gneiss. These difficulties are precisely those encountered in the Adirondacks. Closely interbanded with the limestones and schists of the Grenville are granitic, gabbroic and other gneisses which seem to represent closely contemporaneous igneous intrusions. In other districts, in Clinton county for example, these or similar gneisses are found by themselves and represent the fundamental gneiss, if that formation appears at all in the Adirondack region. From the difficulty of establishing this on the one hand, and of defining any separation from the Grenville rocks on the other, the writer proposed a year ago to refer such rocks to the "Dannemora" formation, the term being wholly provisional, and to apply to areas of gneiss where the distinctive rocks of the Grenville are absent, yet whose proper reference to the fundamental gneiss is wholly doubtful. It is thought likely that these rocks belong with the Grenville series, but it is a convenience to give them a separate designation for the present. In the western Adirondacks Smyth's recent work has shown an abundance of a granitic gneiss which has unmistakable irruptive contacts against the Grenville rocks quite like those to be seen to the north in Canada. Whether these granites are the equivalents of those in the eruptive center of the Adirondacks, or of the Dannemora granitic gneisses, or are wholly distinct from either, seems entirely uncertain at the present time.

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[1] Geol. sur. Can. An. rep't. 1896. v. 8, pt J.

PRE-CAMBRIAN OUTLIER AT LITTLE FALLS, HERKIMER CO.

BY

H. P. CUSHING

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PRE-CAMBRIAN OUTLIER AT LITTLE FALLS, HERKIMER CO.

Little Falls is a locality possessing much geologic interest from several points of view, and has been visited by many geologists. But little attention has been paid however to the nature of the crystalline rocks here exposed.

Vanuxem mentions the rock at this locality as "gneiss," though noting a tendency to assume a porphyritic character.[1] Hall at a much later date calls the rock labradorite (anorthosite of recent reports) evidently regarding it as the same as the Essex county rock.[2]

Kemp (probably following Hall) refers to the reported presence of the "labradorite rocks" at Little Falls, but quotes no authority for the reference.[3]

Prosser and Cumings, in reporting to the state geologist in 1895, make a brief reference to the pre-Cambrian at Little Falls.[4] They refer to the rocks as "gneiss" and as "garnetiferous gneiss", and report it as having a thickness of 203 feet above the river. Their work was specially concerned with the Lower Silurian formations, and the reference to the pre-Cambrian is merely incidental. Since the rock is igneous, the measured thickness has not the significance that would attach to it were it sedimentary. The part of their section from which garnetiferous gneiss was reported was not seen by the writer. This mineral is rare or wholly lacking in the writer's section.

Beyond these four statements the writer has met in literature no reference to the character of these pre-Cambrian rocks. The rock is however not anorthosite (labradorite rock) but syenite. Prof. Smyth seems to have been the first to recognize this, and stated to the writer that such was its character during a conference just preceding the visit to the locality. From specimens brought in by students, Prof. Kemp had also been made aware of the true nature of the rock. That Hall should have called it labradorite instead of gneiss is a mark of his acumen, since the syenite type had not then been recognized in northern New York, and the external resemblance to some varieties of the anorthosite is very close.

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[1] Geol. N. Y. 3d geol. district, p. 19-20.

[2] N. Y. state geol. 5th an. rep't 1885, p. 8-10; reprinted in 14th an. rep't 1894. p. 54-56.

[3] N. Y. state geol. 17th an. rep't 1897, p. 505.

[4] Prosser and Cumings. N. Y. state geol. 15th an. rep't 1895. p. 633.

The writer's visit to the locality was a brief one, not sufficiently long to permit carefully going over the whole ground. First appearing in the river bed west of the village, with surface rising gradually till cut off by the fault at the east edge, where their altitude reaches 200 feet above the river, the extent of the pre-Cambrian rocks in an east and west direction is a little over 2 miles. On neither side of the river the outcrops extend greatly back from it, the breadth being of course greatest at the east.

The writer's time was utilized in making a careful section along the line of the Little Falls and Dolgeville railway, as that seemed to show the most continuous line of outcrops; it is thought that the sections shown in the New York Central and West Shore cuts must be substantially the same. Prof. Smyth has studied the rocks south of the river, as exposed in the cuts of the West Shore road, and our combined results indicate that the exposures are of syenitic rocks throughout.

Though this line affords a practically continuous section for nearly 2 miles, the conditions for study are not wholly ideal. Since the rocks are tremendously jointed, considerable weathering has taken place along the joints, so that the rock has not escaped some alteration, and the exposures consist largely of vertical walls.

The exposed syenite varies widely in appearance and composition, ranging from a fine grained, nearly black rock, which resembles gabbro, to reddish, granitic varieties. All are profoundly metamorphosed and rendered thoroughly gneissoid, much more so than is usual with the syenites of the Adirondack region. The rock is excessively crushed, having a very finely granular texture, yet nearly always uncrushed crystals, or portions of crystals (augen), remain and in places are very numerous, and the cataclastic structure is unmistakable.

General description of the exposures

Near the depot and in the village the rock is more typically syenite than elsewhere. Though the body of the rock is thoroughly granulated, well foliated and with an excellent cleavage, augen abound, reach a larger size than elsewhere, and the rock as a whole is more homogeneous. It has a gray, or greenish gray color, while the feldspar augen are dark and, except for the absence of twinning striations, strongly suggest labradorite. In the more gneissoid portions the augen are alined with their long axes parallel to the foliation, and the cleavage planes run around them, giving a pseudo-flow structure effect.

The general syenite here is quite acid and quartzose (nos. 1, 2, 3).[1] It also varies locally to a reddish, more acid rock (no. 4), which would seem clearly a granite, though it has not been analyzed. All of this rock seen was even more thoroughly granulated and gneissoid than the ordinary syenite, though still showing occasional augen of red feldspar. In both rocks hornblende is the prevailing dark silicate, but the red rock holds much less of it than the other, and consists mainly of quartz and feldspar. These are however quite thoroughly separated and the cleavage is surprisingly well marked and even.

Locally here in the west end of the section the rock has been thoroughly reddened by infiltration of ferric oxid, which has worked its way along the joints into the cleavage planes, thence around the finely granular material and even into the cleavage cracks of the feldspar augen (no. 5). The boundary between the reddened and the unaffected rock is often of the sharpest sort, simulating an intrusive contact. Often little films or sheets of the red color extend out into the ordinary rock, sometimes across and sometimes along the cleavage planes, often mimicking remarkably the penetration of schist by granite.

Going east from the village along the railway, whose rock cut has a steep up grade, the coarse acid syenite is found passing into a finer and more basic rock, and such constitutes most of the remaining exposures. Augen are less numerous and smaller and often disappear. Much of the rock closely resembles gabbro (nos. 6, 7, 10) being black and fine grained, yet in this phase occasional augen are still forthcoming. Sometimes this basic phase is present in considerable amount, but usually it is subordinate to the green rock (nos. 7, 9) and the one passes into the other with facility. Often they appear to be interbanded, but this would be a natural result of the great metamorphism and stretching which have affected the rock, pulling out into bands these somewhat more basic portions.

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[1] The numbers are those borne by the specimens collected, now on deposit in the state museum.

Large crystals of platy, black hornblende have developed along the cleavage planes in many places in these more basic rocks. Occasionally accompanying secondary feldspars are also seen, but ordinarily the hornblende is the only secondary mineral so developed.

Throughout the larger part of the section the green and the black rocks appear in rude bands, which are not usually sharply defined but grade into one another. It is impossible to resist the impression that they are mere phases of the same rock, but the repeated transitions are difficult of explanation. If the black bands represent basic segregations from the magma, pulled out into bands by the stretching incident on metamorphism, their original number was very great. Yet no other explanation of them suggests itself, and the evidence of stretching is impressive. Locally fine grained, gabbroic rocks appear which show sharp boundaries against the syenite and clearly represent later dikes. No case was noted in which such dikes cut the black phase of the syenite, and the writer is still in a state of some perplexity as to the actual conditions, though inclining to the view that most of the black rock is merely a phase of the syenite, in spite of the fact that dikes of a later gabbro are present. This gabbro, moreover, is clearly a closely related rock.

All the rock through the major portion of the section is finer grained and more gneissoid than the rock at the village, with feldspar augen sparingly present, instead of abundant. The green rock is as gneissoid as the black, and the scarcity of augen renders its appearance quite different from that of the rock at the village. The major portion of the rock has been wholly recrystallized, but in many cases the feldspar augen are seen to be surrounded by a rim of granular feldspar which has plainly originated by simple granulation of the edges of the augen.

Some ¾ of a mile east of the depot the rock as a whole becomes gradually more acid (no. 8), and here presents characters not seen elsewhere. It is very thoroughly foliated, almost schistose, in grayish green and black colors, with numerous augen of red feldspar. These differ from the ordinary augen in being, themselves, thoroughly crushed and granular, and being much squeezed and stretched, so that they are usually broadly lenticular, the larger ones being about ½ inch thick and from 2 to 3 inches in diameter. Except that they are wholly inclosed in the rock, thinning out in all directions from their center, they would be taken for injections of fine grained granite parallel to the foliation. There is some resemblance to a stretched conglomerate, but such an origin seems negatived by the fact that the augen are all alike and all of feldspar. If it is simply a phase of the syenite, as it seems to be, it is difficult to see why the augen should be so much more completely granulated here than elsewhere. An apparent intermediate stage is found, however, at the extreme east end of the exposures, a mile away (no. 11). Here a quite similar rock appears, a green and black gneiss with augen of red feldspar. The rock is not so well foliated, and the augen are not so large, but otherwise there is little difference. While some of the augen are entirely granulated, others have a core of uncrushed feldspar, surrounded by a zone of red feldspar grains, whose source is plainly shown, since the usual feldspar of the rock is green, only the augen being red. The wholly crushed augen are not so much stretched as in the previous rock, but a comparison of the two seems to make it quite clear that we have here the same rock, though showing different degrees of metamorphism.

Microscopic characters

The coarser and more acid syenite at the village (nos. 1, 2) is composed of feldspar, quartz, hornblende and biotite, with accessory magnetite, apatite, zircon and pyrite. In much of the rock the hornblende is not fresh but gone to a chloritic aggregate, and at times a little calcite has developed. The accessory minerals call for no comment, except to note that the presence of considerable zircon is the rule in all the Adirondack syenite, and that apatite is more abundant here than is usual.

The feldspar augen show universally a well marked, microperthitic structure, of fine rather than coarse fiber. All show strain shadows, and unmistakable ruptured fragments show frequently. The body of the rock consists of a fine mosaic of feldspar fragments separated by quartzose bands and strings of the dark silicates. This feldspar seems to have entirely recrystallized. Little oligoclase individuals appear here and there, and an occasional fragment shows microperthitic structure, but in most no trace of this can be detected. The lack of this structure, and of the numerous opaque, dotlike inclusions which characterize the augen indicate that these fragments can not have originated by a simple breakage. The chemical analysis shows however that they must have closely the same composition as the augen feldspars from which their material was in all probability derived. Numerous grains of micropegmatite, certainly quite secondary, also appear in this mosaic. Feldspar constitutes from 70% to 75% of the rock.

Quartz is next in abundance and makes on an average 15% of the rock. No quartz augen are to be seen, but the thin section shows it to be disposed in thin leaves of fragmental material, the fragments being of much larger size than the mosaic feldspar. It recalls similar leaf quartz from other syenites and granites in the Adirondacks, though the leaves are much more broken into fragments than usual. Many of these show strain shadows and are full of inclusions similar to those found in the feldspar augen, and it would appear that the quartz was more plastic than the feldspar under the conditions which prevailed during metamorphism, readjusting itself more by stretching and less by breakage and recrystallization than that mineral. In the somewhat less well foliated varieties of the rock the quartz is neither so flattened nor so wholly separate from the feldspar. Neither is the feldspar so finely granular; it may be that the recrystallization of the feldspar preceded the final stretching and granulation.

Hornblende and biotite are the two dark silicates, and the former is much the more important. In fact, the biotite is much more properly regarded as an accessory than as an essential mineral. Together they constitute from 10% to 15% of the rock. They are stretched out together along the cleavage planes, not appearing elsewhere in the more foliated varieties, but like the quartz less well alined in those less gneissoid. Both are perfectly ordinary representatives of the two minerals and call for no comment.

The more acid phases of the rock here (no. 4) have only about half the usual amount of hornblende and biotite, and a larger quartz percentage. The feldspar augen are red instead of dark colored, though consisting of the same minute fibered microperthite. They are few in number and of small size, and are always partly and often wholly granulated. Considerable microcline appears in the mosaic feldspar. The quartz is as before, and the rock practically consists of these thin, parallel quartz leaves with intervening fine feldspar mosaic. In the absence of an analysis, it is impossible to say just what the acidity of the rock is, but, since the ordinary rock shows 66% of silica, this would appear to have at least 70% and to be properly classed as a granite.

The two augen gneisses previously described are like the last in having red feldspar augen. In no. 8, in which the augen are completely granulated, microcline is more abundant than elsewhere, though as usual anorthoclase is the prevailing feldspar, the larger grains showing a faint microperthitic structure with high powers. There is also quite a little micropegmatite and the usual small amount of oligoclase. Here biotite is the prominent dark silicate and is quite abundant, while hornblende much retreats. It seems quite probable that all the biotite in these rocks has resulted from the alteration of hornblende during metamorphism, in which case its abundance in this specially mashed and stretched rock is quite what would be expected. There is from 15% to 20% of quartz in the rock, mainly in leaves and lenses as usual. The rock quite plainly belongs with the acid syenites such as no. 4 and is merely an extra-stretched representative. The original crystals from whose mashing the present augen have been derived were of much larger size than in any other of the red rocks seen.

The augen gneiss at the east, near the fault (no. 11) is more basic than any of the foregoing, though clearly belonging with them. It contains some 30% of dark silicates and not more than 10% of quartz. Augite, bronzite, hornblende, magnetite and garnet are all present, and there are also a few fragments of what appears to be brown hornblende, but the identification is not certain. The garnet is usually idiomorphic, though one or two instances of corrosion rims around magnetite occur. Apatite and zircon are abundant and often of large size. So far as these minerals go, the rock is precisely like the ordinary Adirondack gabbro, except for the zircon. But there is considerable quartz of the usual flattened type, and the feldspar is mainly of the indefinite microperthite or else of a curious and striking micrographic sort of intergrowth. There is in addition some little plagioclase, whose extinction angles would indicate a basicity at least that of andesin and some micropegmatite. The quartz and feldspar are therefore quite as in the previous rocks. The metamorphism, however, has not been so severe. The rock must approach to monzonite in composition.

The slide of the more basic, blackish syenite (no. 10) is from the rock at the quarry, near the top of the hill and less than ½ mile from the fault line. The exposures are excellent here and show fine grained, thoroughly gneissoid rocks, both the green and black phases being present in quantity and grading into one another. The green rock is identical with the syenite at the village (nos. 1 and 2) except in the lack of feldspar augen and in being a trifle more basic.

The black rocks show infrequent augen of dark color which are usually bordered by a green cataclastic zone of shattered feldspar fragments. The dark silicates constitute from 40% to 50% of the rock. Bronzite is preponderant, augite and hornblende are also present in considerable quantity, and a little biotite appears, usually around magnetite, of which considerable is at hand. No garnet appears, but apatite and zircon are prominent, and some little pyrite occurs also. The rock is very finely granular, with a few feldspar and quartz fragments of somewhat larger size. There is nearly or quite 10% of quartz, a large content for so basic appearing a rock.

About 10% of the feldspar is plagioclase. In the half dozen fragments properly cut the prevailing extinction angle measured from the albite twinning plane is 10°, in one case however reaching 17°. The mineral is probably andesine. The remainder of the feldspar is of intergrowth types, mostly of the prevalent faint microperthite. There is also present considerable of a micrographic intergrowth of an unusual and striking type, identical with that in the augen gneiss just described (no. 11). The rock as a whole clearly is a basic phase of the syenite. It is considerably more basic than the augen gneiss (no. 11) and would seem a quite typical monzonite.

The most basic rock collected was obtained about ½ mile east of the depot. It is a heavy, fine grained, black rock (no. 6) in which no augen were noted. It contains 50% of dark minerals, abundant hypersthene (or bronzite), augite, hornblende and magnetite, some biotite and a little garnet, this latter idiomorphic and not around the magnetite. As usual, there is considerable apatite, but zircon is not so abundant as in most of the syenite. Most of the biotite is primary apparently, though in part it results from hornblende alteration. All of these minerals are quite as in the preceding rocks, except that the orthorhombic pyroxene is rather more strongly pleochroic and may be hypersthene instead of bronzite.

Quartz makes some 5% of the rock. It shows a tendency to the flattened form, though not so pronouncedly as in the more acid rocks. The general identity of all these minerals with those in the other rocks is emphatic evidence of their relationship.

The feldspar however differs. More than half of it consists of well twinned plagioclase whose extinctions reach 21°, indicating an acid labradorite. But there is also a large amount of the curious micrographic intergrowth like that in the preceding rocks. For the most part both of the feldspars of these intergrowths are untwinned, but an occasional labradorite fragment shows a similar intergrowth. This renders it possible that untwinned labradorite is one of the feldspars of the usual intergrowth, though this is not thought likely.

This rock is strictly a gabbro (norite), though with a syenitic facies. The identity of its component minerals with those in the other rock sufficiently establishes its relationship to them, however. No sharp line can be drawn between any of the varieties, since all gradations are found, yet the rock ranges from a granite to a gabbro in composition. In the frequency and amount of such change it is quite like the syenite of the Adirondack region, but, considering the slight areal extent of the exposures here, the amount of change is surprising. The accessibility of the locality and the excellence of the exposures combine to render it well worth a visit.

Chemical composition

A thorough chemical study of the Little Falls rocks could not fail to furnish results of great interest, though the writer is strongly of the opinion that the table of analyses would be quite similar to that of the various syenites given in the preceding report.

The single analysis so far available is that of the ordinary augen syenite at the village (analysis 13 of the preceding report). A precise calculation of this rock can not be made because of the unexplained failure of the ferrous iron determination. Assuming that 1% of magnetite is present, which can not be greatly wide of the mark, that the alkalis are wholly in the feldspar, and that the excess of alumina is in the hornblende and excess of lime in the anorthite molecule, the calculated composition is:

Quartz	Orthoclase	Albite	Anorthite	Hornblende	Magnetite
12.67%	33.42	36.84	4.17	12.02	1

Total 100.12

This can not depart widely from its actual composition. The rock is an acid quartz syenite, in its high soda percentage showing affiliation with the monzonite group.

Diabase dikes

Nearly a mile east of the depot the rock cliff is broken by a small gully, apparently along a fault line. Forming the east wall of this gully is the largest diabase dike which it has been the writer's fortune to see in northern New York. It is at least 120 feet wide, bears n. 70° e., and shows numerous and large porphyritic feldspars, often an inch and more in length. As would be expected from its width, the dike rock is fairly coarse grained, though with the usual chilled borders.

The rock is not fresh. So far as can be told, it consisted simply of plagioclase, augite and magnetite. There is no indication of olivin. As is the case with most of the Adirondack diabases which lack olivin, the feldspar preponderates much over the augite, and the structure is not ophitic, though the feldspars are lath-shaped. Prof. Smyth informs me that there are specimens from two diabase dikes from Little Falls in the Hamilton college collections. The interest attaching to their presence is that such dikes are very rare in the southern and western Adirondacks, though abundant on the north and east. The fact that at least two are present in this small outlier is an indication that they probably reappear in force here under the Paleozoic cover. It is inferred that these dikes are pre-Cambrian, since that is the age of the Adirondack diabase, and since the dikes which are found cutting the Paleozoic rocks of the vicinity are of a wholly different rock, alnoite.

Age of the syenite

Since this outlier shows no other crystalline rocks than the syenite and diabase, any discussion of its age can be but tentative. Yet, since the various pre-Cambrian outliers expose no rocks other than those found in the Adirondacks, the same rude correlations will apply which are attempted there.

The Little Falls syenite differs slightly from the usual Adirondack syenite. It is unlike that of Franklin county in its gray, rather than green color, in its very evident cataclastic structure and much more pronounced foliation. The feldspar augen often reach a length of an inch or more, while the remainder of the rock is very finely granular. The Franklin county rocks are more even grained, the augen are comparatively few and small, and the body of the rock is far coarser than the granular portion of the Little Falls rock. These differences largely disappear in the more basic varieties, but the Franklin representatives are, again, usually coarser. These differences are mainly attributable to the more severe metamorphism at Little Falls. But the combination of numerous and often large feldspar augen with very fine grained matrix, is not to be thus explained, and seems to the writer to point to an original porphyritic structure in this rock. Had the original grain been equidimensional, it must have been very coarse in order to permit of such large remaining augen, and it is difficult to see how metamorphism could so profoundly change most of the rock and yet leave such large crystals unaffected. But, if these represent original porphyritic crystals, the complete shattering of the finer portion of the rock might be easily effected without great damage to the rest. Porphyritic phases of large granite and acid syenite bodies are of frequent occurrence; and the assumption here would afford a reasonable explanation of the somewhat abnormal character of the rock when compared with the usual Adirondack syenite.

The Diana syenite seems to possess a strictly intermediate character. Its color is nearer to that of the Little Falls rock, but its augen do not approach those in size, nor is the residue of the rock so fine grained and gneissoid, though the augen are usually surrounded by a narrow zone of very fine, cataclastic material. The writer is therefore disposed to class all these syenites together, as springing from the same magma at the same time or at least at times not remotely separated. Certainly this is the most natural view, in default of direct evidence to the contrary.

In this connection, it should be noted further that the plane differentiation exhibited by the syenite here at Little Falls would seem to afford corroborative evidence of the truth of the view advanced in the preceding report, when considering the general relationships of the great eruptive masses of the Adirondacks. The small eruptive mass at Little Falls shows variation to granite and to gabbro as the two extremes. The rather basic augite syenite dikes described as cutting the anorthosite at various places, in the preceding report, and which were inferred to be offshoots from the main syenite intrusion and to indicate the younger age of that intrusion, are in all respects like some of the more basic phases of the Little Falls rock, where they appear as unquestionable variations of the syenite. There is also suggested the further query, whether some of the Adirondack gabbro should not also be classed as of the age of the syenite and as a direct derivative from it. There is certainly gabbro of such origin at Little Falls, and may well be elsewhere.

Structural notes

Most of the rock at Little Falls is sufficiently well foliated to permit satisfactory dip and strike observations. At the village the foliation planes strike east and west, with dip 15 s.; ½ mile farther east the strike is n. 60 w. and dip 20 n.; ½ mile farther the strike has swerved back east and west, and near the fault line it is n. 80 w.

At the village the main pair of joints are vertical and trend to n. 20 e. and n. 50 w.; 1 mile to the east, readings of n. 30 e. and n. 60 w. were obtained on the same pair. These joints vary but little in direction throughout the exposures, follow one another at distances of from 1 to 3 feet, and are very evenly and sharply cut. Often also good horizontal jointing appears, and there seems to be another vertical set bisecting the angles of the first, but much less well marked.

PRELIMINARY REPORT OF FIELD WORK IN THE TOWN OF MINERVA, ESSEX CO.

BY GEORGE I. FINLAY

The town of Minerva in Essex county covers an area of approximately 175 square miles. The Hudson river is here the principal stream. Its course holds strongly to two directions. It comes into Minerva on a very straight course 15° west of south. At the point where Indian river, which flows along this same direction, joins it, the Hudson turns abruptly and flows in a line 15° south of east to Dutton mountain, where it bends almost at a right angle to resume its former course. This is also the direction taken by the Boreas river, which flows down from the north to join the Hudson river near Dutton mountain. Minerva creek and Trout brook in the southeastern part of the town are strictly parallel with the main course taken by the Hudson, whereas Cedar river, which joins the Hudson from the northwest, Jones brook and the lower part of Trout brook in the southeastern corner of Minerva are all parallel with the middle branch of the Hudson. This direction is nearly that of the grain of the country. The other direction is at right angles to it.

The surface of Minerva shows very considerable relief. Vanderwhacker mountain in the north reaches an altitude of 3385 feet, while Wolf creek at its base drains a swampy area lying at a hight of 1650 feet. Polaris, Beaver, Bad Luck, Casey, Black, Venison, Dutton and Moxham mountains are all well above 2000 feet, as are also Hewitt Pond hill and Oliver and Snyder hills. There are about 40 lakes and ponds within the limits of Minerva, situated chiefly at low levels, in the north and west. Olmstedville and Minerva in the southeast are almost the only villages. Probably three fourths of the town is a wilderness.

The country rock is a gneiss having the composition of granite. With it is associated a larger amount of crystalline limestone, accompanying schists and hornblendic rocks, than is usual in other parts of the Adirondack area. Much of northern Minerva is occupied by anorthosite, the contact between the anorthosite and the gneiss being found just south of Aiden Lair. Anorthosite occurs on the hill in the extreme southeastern corner of Minerva, a mile and a half from Pat pond. Excavation on McKee's farm at the foot of the hill exposed the contact between anorthosite and gneiss, and showed small amounts of pyrite and other sulfids. A few small outliers of gabbro are to be mentioned, but the present paper has to do principally with the relations between the gneiss and the limestone, with a view to the recording of such facts as bear on the question of the sedimentary, or nonsedimentary origin of the gneiss and associated schists.

It will be seen by an inspection of the map that the forms of high relief are of gneiss, while the limestone is found occupying the valleys. The largest area of limestone extends from Trout brook, east of Olmstedville, to a point 3 miles northwest of the town of Minerva. An outlier runs up the valley a mile beyond Irishtown, and a second reaches over toward Dutton mountain. Smaller areas occur east of Huntley pond, south of Black mountain and along the Hudson, which is rapidly cutting its bed on limestone from the mouth of Cedar river to Blue Ledge.

The crystalline limestone preserves the character which is common to it in many other parts of the Adirondack area. It is uniformly coarse grained and when much decomposed by weathering it gives a coarse gravel-like soil. In the metamorphic processes to which the region has been subjected the limestone has been very sensitive to pressure. It yielded most often along certain planes where the dark silicates appear drawn out in flow lines. Bands of dark silicates much squeezed and contorted, several inches in width, result in this way, as well as rounded masses, often several feet across. Many of these are well exposed in the ledge near Mr Owen's house south of Dutton mountain. Hornblende in large crystals is found associated with limestone on the Minerva road just west of Olmstedville. Flecks of graphite in the limestone are very generally conspicuous. The graphite is commercially important however in but one locality near the boundary line of Essex and Warren counties at the base of Green hill. The prospect has been opened where a thin band of limestone is in contact with gneiss. The "bluestone" which yields the best return is a greatly decomposed limestone.

Perfectly regular and continuous bands of dark rock are also common in the limestone. These are from 1 to 2 inches wide. They run at times for 20 or 30 feet parallel to each other, and 6 to 8 inches apart. They are well seen in the white graphitic limestone half a mile from Minerva on the road to Irishtown. They consist essentially of hornblende and feldspar. The hornblende is in large rounded crystals, colored dark bottle green. It is strongly pleochroic and but little broken up by cleavage cracks. Occasional hypersthene is the only other dark silicate. With these are associated orthoclase and often abundant plagioclase. This rock is invariably found with the limestone, and it carries garnet at times. A prospect hole for garnet on the hill southwest of Calahan pond shows limestone above as a hanging wall, with the hornblendic rock containing large lenses and rounded masses of garnet as the footwall. Here several tons have been broken out, but, though the garnet is of good quality, it is not found in quantity sufficient to justify further exploration. It is on the contact between the hornblendic rock and the limestone that we can best determine the special relations of the limestone. It is found to vary but little from n. 30 w. to n. 50 w. on the strike. The dip is from 20° to 80° to the northeast. The limestone frequently shows minor folds. A small anticline with axis n. 52 w. is found on the west bank of the Hudson, half a mile below the mouth of Cedar river. Along the bank of Minerva stream, where the road crosses leading east from Olmstedville, the limestone is exposed, overlain by the hornblendic rock and so folded as to give a gentle syncline and two sharper rolls. The exposures of crystalline limestone are often so massive as to show but little or no trace of the former bedding planes, and again they are visibly contorted. This is well seen south of Black Pond mountain. The brook just north of the road and parallel with it at this point runs part way on gneiss (strike n. 49 w., dip 21 n. e.) but at the contact between gneiss and limestone it plunges 15 feet in a waterfall. The limestone from this point has been largely removed by the cutting of the stream below the waterfall, and the exposed section exhibits the lines of dark silicates drawn out in every direction from n. 40 w. to n. 15 e. It is not possible to prove the existence of a fault, and the relations between limestone and gneiss at this point are therefore not those which obtain between beds in a sedimentary series.

The gneiss of Minerva township is a heavily bedded rock of a light gray or brownish gray color. It is of medium grain and varies but little from place to place. The combination of quartz and microcline with more or less plagioclase is characteristic of it. The feldspar and quartz occur as rounded or subangular grains often with layers formed of larger masses of quartz drawn out in lenses. The single grains of quartz are not much broken up by cracks and do not appear to have been greatly crushed by metamorphic processes. Recementing of the grains by secondary quartz or feldspar was not observed. The quartz is characterized by minute inclusions of rutile, and by having many of its cracks filled with microscopic dendritic growths of MnO_2. The microcline exhibits the usual lattice structure. The plagioclase shows very fine twinning lamellae, and broad ones, alternating. Granophyric growths with orthoclase may be observed. The plagioclase usually occurs as an accessory to the microcline but it may be almost the only feldspar present. On the western slope of Snyder hill the gneiss is locally almost pure feldspar. Biotite is the usual dark silicate. It often appears altered to chlorite. Garnet is common. Apatite occurs sparingly, but the crystals are of unusual perfection with the basal cleavage but little developed. Magnetite is commonly met, and epidote, in bottle green crystals well terminated at one end, has been observed.

The gneiss is almost always found in Minerva township with a strike from n. 25 w. to n. 50 w. The dip is usually to the northeast and runs from 20° to 40°. This general concordance in strike and dip between the heavy bedded gneiss and the limestone was not suspected till over a hundred localities had been visited, but the relation is found to be persistent throughout the town. It must be taken to explain the areal extent of the limestone along a general n.w.-s.e. direction. The limestone is found occurring in numerous bands, which the valleys follow. These courses are the directions taken by several of the rivers, and where the streams do not follow along the soft limestone beds, they cut across the strike at a right angle and thus take the next most economical course for them. The middle branch of the Hudson river in Minerva represents the course taken by a branch stream, on soft limestone, in effecting the capture of the upper waters of the Hudson. The "fishhook" bend taken by that river at Gooley is characteristic for stream capture.

Extended sections of the gneiss are met in going up Beaver, Moxham, or Dutton mountains. Frank, Split rock, Mink, Beaver and Thumb ponds have their beds in the gneiss and show many exposures along their shores. They are connected by swamp lands, or are separated by almost imperceptible divides. The gneiss extends westward into Hamilton county, where it is associated with limestone, at the Chain lakes. First, Second, Sixth and Seventh lakes are entirely in the gneiss, and the same rock is found along the north shore of Fifth lake. Third lake lies on the contact between the gneiss which appears along its southern edge, and the limestone. The latter, of the usual coarsely crystalline graphitic variety, is found standing in bold cliffs along the north shore.

The gneiss is exposed in a single section of nearly 100 feet in the hill halfway between Sherman pond and the pond which is drained by Deer creek. Many alternating bands occur, coarse and fine, with members so rich in mica as to go over toward the schists. A band is found toward the top which is almost entirely coccolite and quartz. The pyroxene is in light green granular crystals. The extinction angle and interference colors are high. The quartz is notable for its inclusions of garnet. These are colorless and give six-sided or rhombic sections. They are bounded by faces of the rhombic dodecahedron (101).

Exposures of the gneiss with associated bosses of gabbro were found near Deer creek, a mile to the west of Callahan pond, along the western side of the road just south of Irishtown, and on the southeastern spur of Snyder hill. The idiomorphic feldspar seen under the microscope is labradorite. It is twinned on the albite law in broad lamellae and has the usual clouded habit of the feldspars in gabbro. The single lamellae are filled by innumerable rods and dots irregularly placed, probably magnetite microlites. These are frequently very abundant and of minute size in one lamella and coarser and far less abundant in the succeeding band. Other feldspar inclusions are in the nature of larger, oriented rods, such as would indicate the passage of iron-bearing waters along solution planes. The dark silicates are irregular, clear green masses of hypersthene, and abundant biotite, in red brown shreds, favoring association with grains of magnetite. The rock also carries garnet.

An interesting phase of the gneiss is found at the point where the road leading to the North Woods club crosses the Boreas river. The feldspar is a reddish pink orthoclase. This rock extends for over a mile up stream on the western bank of the river.

The relation between the gneiss and the limestone with its associated schists and hornblendic bands, is not left doubtful, though, in the majority of instances where the rocks outcrop together, the differential effects of metamorphism on the gneiss and on the far more sensitive limestone are such as tend to disguise it. The limestone one and a quarter miles to the east of Huntley pond is exposed conformably interbedded between gneiss and quartzite. A six inch band of limestone is found along the Hudson river a little southeast of Pisgah mountain, regularly bedded with gneiss above and below it. East of Bullhead pond, along the road, gneiss is again found with a bed of limestone, the two exhibiting the same strike and dip. The limestone is exposed with gneiss lying conformably above it at a point just south of the stream which flows into Jones brook, 2 miles northwest of Olmstedville.

The average strike of the limestone over wide areas is the same as that of the gneiss. Where the two rocks are seen side by side, they appear together conformably or the limestone has suffered from the compressive forces of metamorphism so considerably as to have completely lost its original bedded character. The contortion has at times been so great as to amount to flowing under conditions of plasticity. The accompanying effects on the gneiss resulted in the production of a monoclinal structure throughout the township. It was not possible to establish definite folds. Examination in the field makes it plain that faulting is much rarer here than elsewhere in the Adirondacks. The small stream which joins Jones brook nearest to its union with Minerva stream, probably owes its position to a fault line, but the sawtooth structure of other regions, where blocks have been commonly faulted and tilted toward the east, is not found over this area. On any supposition the pre-Paleozoic series of metamorphosed sediments in Minerva township must be measured by many thousands of feet.

PLEISTOCENE GEOLOGY OF WESTERN NEW YORK
REPORT OF PROGRESS FOR 1900

BY

H. L. FAIRCHILD

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PLEISTOCENE GEOLOGY OF WESTERN NEW YORK

INTRODUCTION

The work during the summer and autumn of 1900 was in continuation of the study of the glacial lake history of the western half of the state, which had been prosecuted for several years. The territory lying between the Tonawanda and Limestone creeks, covering the interesting district of the "Finger lakes," and the Genesee valley, had already been covered in a general way. The results of these vacation studies have been published in several papers in the scientific journals since 1895.[1]

Three districts were examined during the season of 1900, as follows:

1 A special study was made of the Iroquois shore line between Richland and Watertown, and the constructional features were mapped. The study had special reference to rate of differential elevation of the beach.

2 In eastward extension of the previous investigation, the territory between Syracuse and Oneida was studied with special

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[1] Glacial lakes of western New York. Geol. soc. Am. Bul. Ap. 1895. 6: 353–74.

Lake Newberry the probable successor of Lake Warren. Ibid. 6:462–66.

Kame-moraine at Rochester N. Y. Am. geol. July 1895. 16:39-51.

Physical characters of Monroe county and adjacent territory. Roch. acad. sci. Proc. Jan. 1896. 3:28–38.

Kame areas in western New York, south of Irondequoit and Sodus bays. Jour. geol. Feb.–Mar. 1896. 4:129–59.

Glacial Genesee lakes. Geol. soc. Am. Bul. 1896. 7:423–52.

Lake Warren shore lines in western New York, and the Geneva beach. Geol. soc. Am. Bul. Mar. 1897. 8:269–86.

Glacial geology of western New York. Geol. mag. Lond. Decade 4. Dec. 1897. 4:529–37.

Glacial geology in America. Am. ass'n adv. sci. Proc. Aug. 1898. 47:257–90; Am. geol. 22:154–89; Sci. Am. Sup. Sep. 1898. nos. 1183–85.

Kettles in glacial lake deltas. Jour. geol. Sep.–Oct. 1898. 6:589–96.

Glacial waters in the Finger lakes region of New York. Geol. soc. Am. Bul. Feb. 1899. 10:27–68.

Glacial lakes Newberry, Warren and Dana in central New York. Am. jour. sci. Ap. 1899. 7:249–63.

reference to the higher, and earlier channels cut by the overflow of the glacial waters.

3 In westward extension of the study, a large area was examined in Cattaraugus and Chautauqua counties.

The glacial phenomena are so varied and complex, specially in the last two districts, and the territories so large that it was not possible in one season to complete the study. However, it is desirable to describe some of the phenomena with considerable fulness and detail in this report. The districts will be taken up in the order given above.

1 THE IROQUOIS SHORE LINE

Introduction, historical

The ancient, high-level beach phenomena in the Ontario basin were noted by the early settlers and travelers, and their character as beaches was generally recognized. They were the subject of study and printed notice by Thomas Roy (1837), Lyell, Hall and others long before their glacial relationship was recognized. The earliest description of these ancient shores in New York state was by Prof. James Hall, in the *Geology of New York; 4th geological district*, p. 348–51. In his chapter on lake ridges he marshals the facts in proof of their beach origin, and describes their form and structure. He also discusses briefly their relationship to the land surfaces of central New York, and their hight above Lake Ontario. The elevation of the beaches he attributed to changes in land level, and admitted the possibility of their marine origin. As he was personally acquainted with only the stretch between Niagara and Sodus, he did not recognize the deformation of the shore line from the horizontal.

In recent years these beaches have been traced in New York state by G. K. Gilbert, and in Canada by J. W. Spencer. It has been demonstrated, specially through the work and writings of Mr Gilbert, that the beaches are the shore of a great lake which had its outlet at Rome N. Y. to the Mohawk valley, and was held up to that level by the continental ice sheet, which covered and blocked the St Lawrence valley. The name Iroquois was given to the beaches by Spencer, though he did not recognize their lacustrine origin. Only very generalized maps were published in the writings,[1] and no detailed description of any considerable stretch of the shore has ever been printed.

The map of Lake Iroquois (pl. 19) prepared to accompany this report is not intended to be exact in minor features. Within the area many drumlins and other high points were islands in the lake. A few of these islands are indicated in the district between Syracuse and Oswego. For the boundaries in Canada the writer has used the sketch map published by Dr J. W. Spencer, and for part of the New York boundaries he is indebted to Dr G. K. Gilbert. Toward the St Lawrence valley the shores are not determined.

Tilting of shore line

In the papers referred to above was discussed the deformation or differential uplift of the Ontario basin, which has largely or wholly occurred since the extinction of Lake Iroquois, thereby causing a present northward rise of the beaches. Between Richland and Watertown the beach has an average slope of over 5 feet to the mile,[2] or something over 135 feet in the 26 miles of direct distance.

The northward direction of the beach in this section with its decided slope and well developed characters makes it probably the most interesting and desirable portion of the whole Iroquois shore line for the study of the differential elevation. Following a suggestion of Mr Gilbert, the writer undertook the examination of the beach in order to discover if it indicated that any porɔn of the tilting occurred during the life of the lake. If su ovement did occur in any considerable degree, it ought to b own by the northward increase of the vertical distance betwee e upper and lower bars, as this portion of the shore line lies ırth of the outlet at Rome.

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[1] Spencer, J. W. Terraces and beaches about Lake Ontario. Am. jour. sci. 1882. 24:409.

—— The Iroquois beach; a chapter in the geological history of Lake Ontario. Roy. soc. Can. Trans. 1890. 7:21, ser. 4.

—— Deformation of Iroquois beach and birth of Lake Ontario. Am. jour. sci. 1890. 40:443.

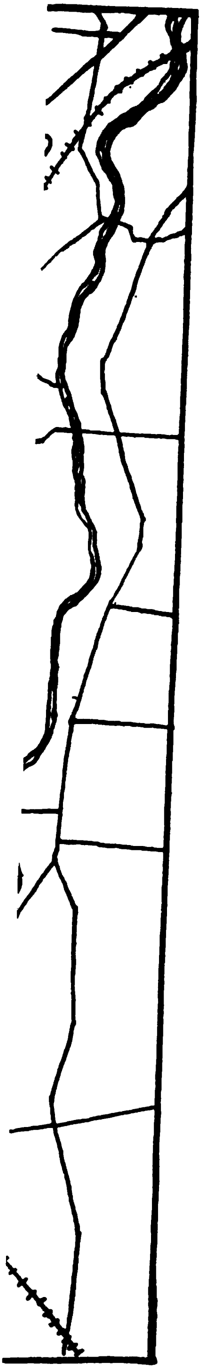
Gilbert, G. K. History of Niagara river. Com. Niag. reservation 6th an. rep't. Alb. 1890.

[2] At Richland the railroad station has an altitude of 522 feet A. T., and the upper bar is 44 feet above, or 566 feet. At Brookside cemetery, 2 miles south of Watertown, the upper bars lie on, or above, the 700 foot contour of the New York topographic map, Watertown sheet.

Maps and profiles

A rapid survey and mapping was made of the constructional atures, as embankments, bars and spits, through about 30 miles the shore line. These features are shown on the accompany g map (pl. 9). No attempt was made to trace the initial shore ıes, which lie at varying distances landward and are very egular, as they are indefinite and useless for the present study. At frequent intervals profile cross-sections were made of the veral bars composing the beach. The location of such profiles indicated on the map, and they are also plotted on a chart for mparison (pl. 10). On this chart the 25 profiles are numbered ɔm south to north, and they are correspondingly numbered on e map.

In the chart of profiles the vertical scale is five times the hori ntal, that is to say, the squares represent 50 feet vertically, and 0 feet horizontally. The numerals in two figures on the bar ests of the profiles indicate the hight in feet above the low ound at the edge of the sublacustrine plain; those in three ures indicate the hight above sea. The location of the high ıys and of the Rome, Watertown and Ogdensburg railroad are dicated by suitable marks. The profiles of the chart are not ıced in their exact geographic relationship, either horizontally in the distance apart, but the highest bar, or the one farthest ndward, is given nearly the same position at the right side of e chart. The distances between the cross-sections are given miles by the numerals placed between the profiles. The aight line distance covering the 25 profiles is 26 miles; the stance following the curves of the beach is about 28 miles. ı the diagram the profiles are divided into several groups, des nated by letters, each group lying within a section of the shore o face p. r108



line where the topographic conditions were similar and the agencies tended to make the shore features comparatively uniform.

The horizontal measurements for the profiles were partly by eye estimate and partly by pacing; this element, which is less important, is therefore only approximate. The vertical measurements were usually by hand level, and sometimes repeated, and the error in this important element is probably not much greater than is the variation in the surface of each individual bar.

Composition of the bars

The material or composition of the bars, whether coarse or fine, was not always recorded, but it is usually either sand or finer gravel, rarely coarse gravel. This factor may possibly be of critical importance, as indicating depth of water. However, the composition of the bars is thought to depend chiefly on other conditions than depth, as the character, abundance and proximity of the supply; the exposure to the wind or the force of the waves; the depth off shore; the strength of the shore currents.

Vertical relation of the bars

The significance of the bars with reference to changes of lake level lies in the element of vertical relation. For purpose of comparing the vertical spacing the chart of profiles (pl. 10) has been prepared, and the tabulation p. 110. The figures in the second column, for the highest bars, are inexact only to the degree of uncertainty in selecting a basal point on the lake bottom plain, which is not very difficult since this plain is quite definite. However, any error here does not in the least affect the figures in the other columns. The figures of the third and fourth columns are accurate, the only and rare uncertainty being the determination of the highest bar. As shown by the map, the bars are not continuous, and therefore there is not absolute certainty of the identity or exact correspondence of the highest bars of the different sections. However, considering the long stretches of continuous beach, the large number of sections, and the long distance which they cover, the practical identity of the upper level can properly be assumed.

The only interval between any two adjacent bars of this shore which appears to have any value for purpose of comparison is that between the highest bar and the next well developed bar below. This was first suggested by the bars immediately south of Adams,[1] where two strong bars occur, the summit bar and the next below, with a vertical difference of 27 feet. These bars are conspicuous even from the railroad. The vertical separation seems too great to permit the two bars to have formed at the same time, specially as the lower bar is ordinary fine beach gravel.

Table of vertical relations

No. of cross-section	Distance of highest bar above the plain	Vertical distance between highest bar and next strong bar lower	Vertical distance between highest and lowest bars
	Feet	Feet	Feet
25	..	37	51
24	35	10	..
23	25	?	..
22	..	?	..
21	41	?	14
20	35	14	24
19	41	19	19
18	48	?	28
17	50	27	42
16	40	27	27
15	63	27	40
14	41	35	35
13	63	35	43
12	51	24	24
11	51	16	16
10	58	16	38
9	61	18	41
8	41	15	36
7	57	11	38
6	60	15	39
5	45	13	37
4	57	?	35
3	42	?	..
2	50	?	..
1	44	22	22

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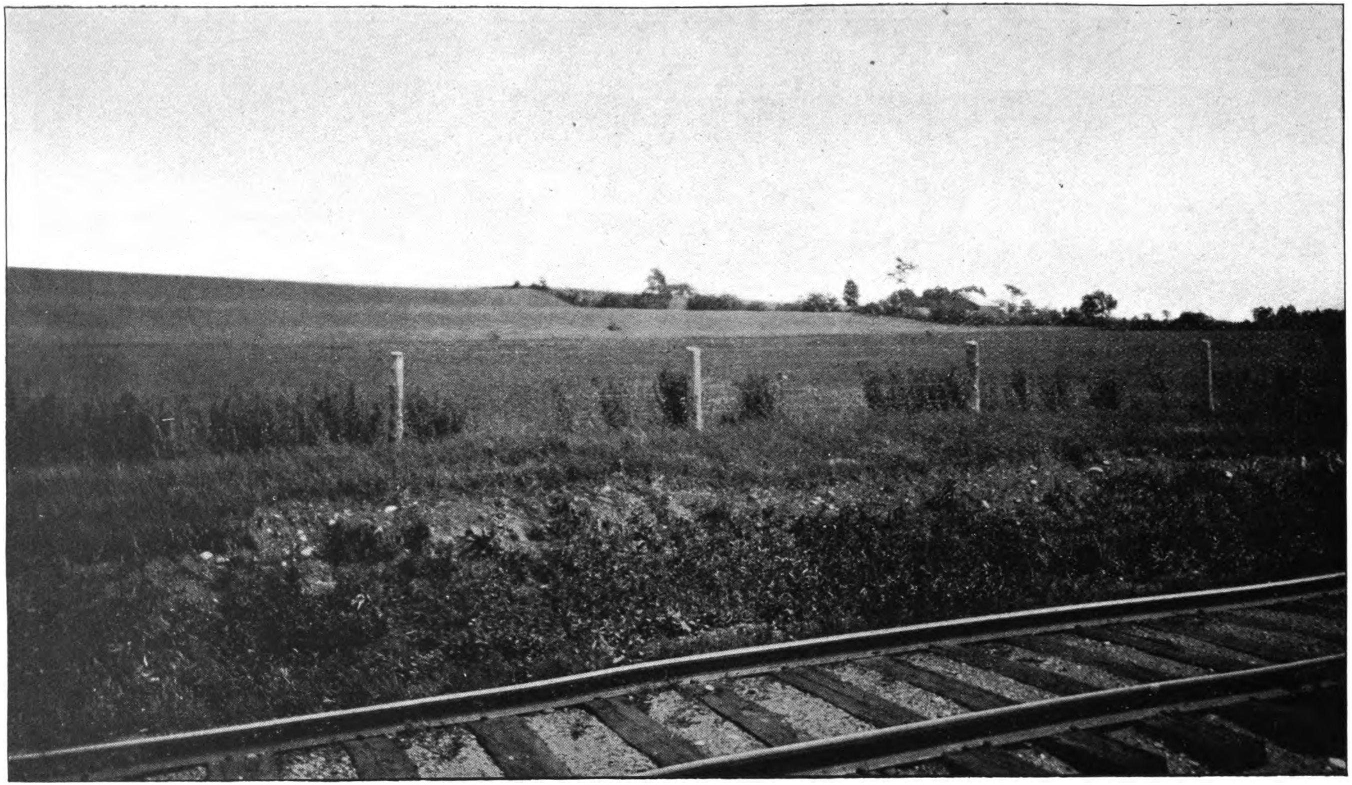
[1] *See* chart of profiles, group G, nos. 15, 16, 17, also pl. 11, 12.

Plate 11



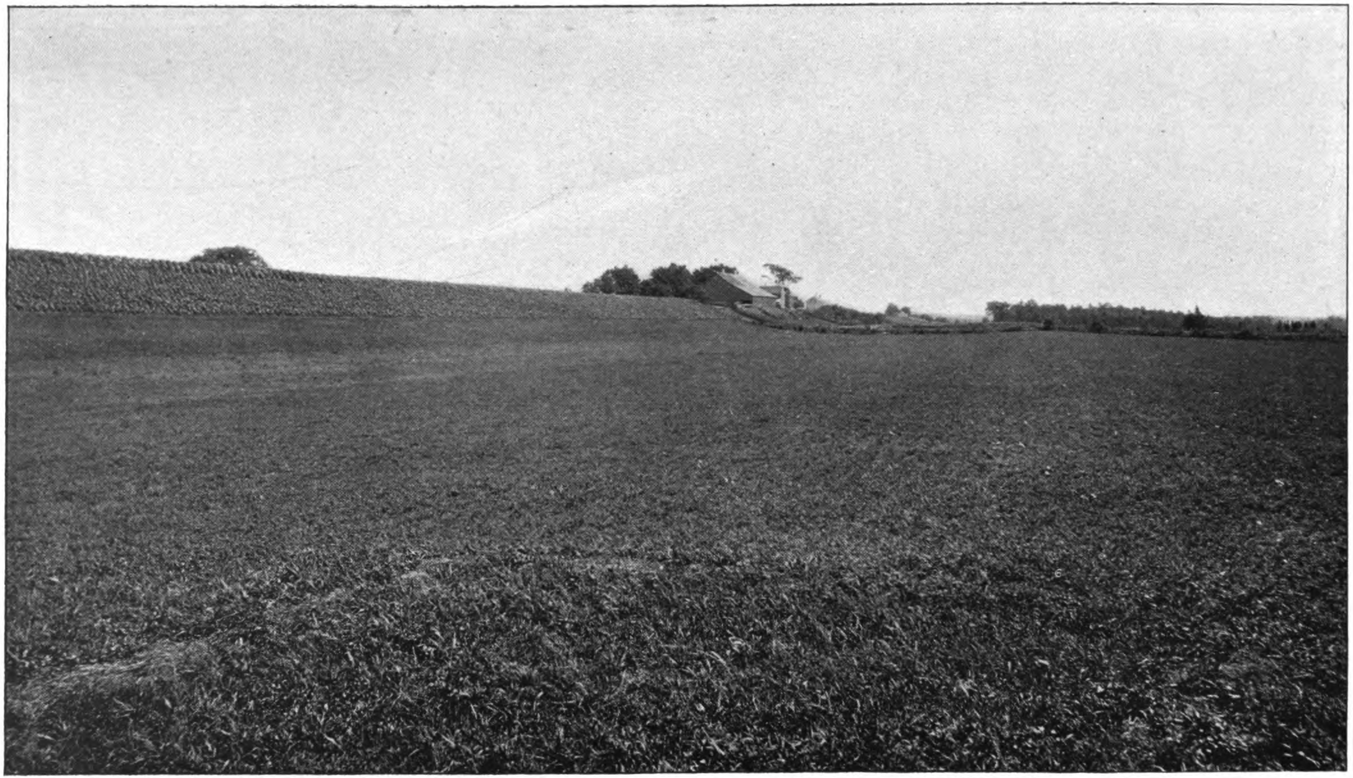
H. L. Fairchild, photo.

SHORE OF LAKE IROQUOIS

Three bars, ½ mile south of Adams. Looking s. 20° e. (Compare pl. 12)

Plate 12

To face p. r110

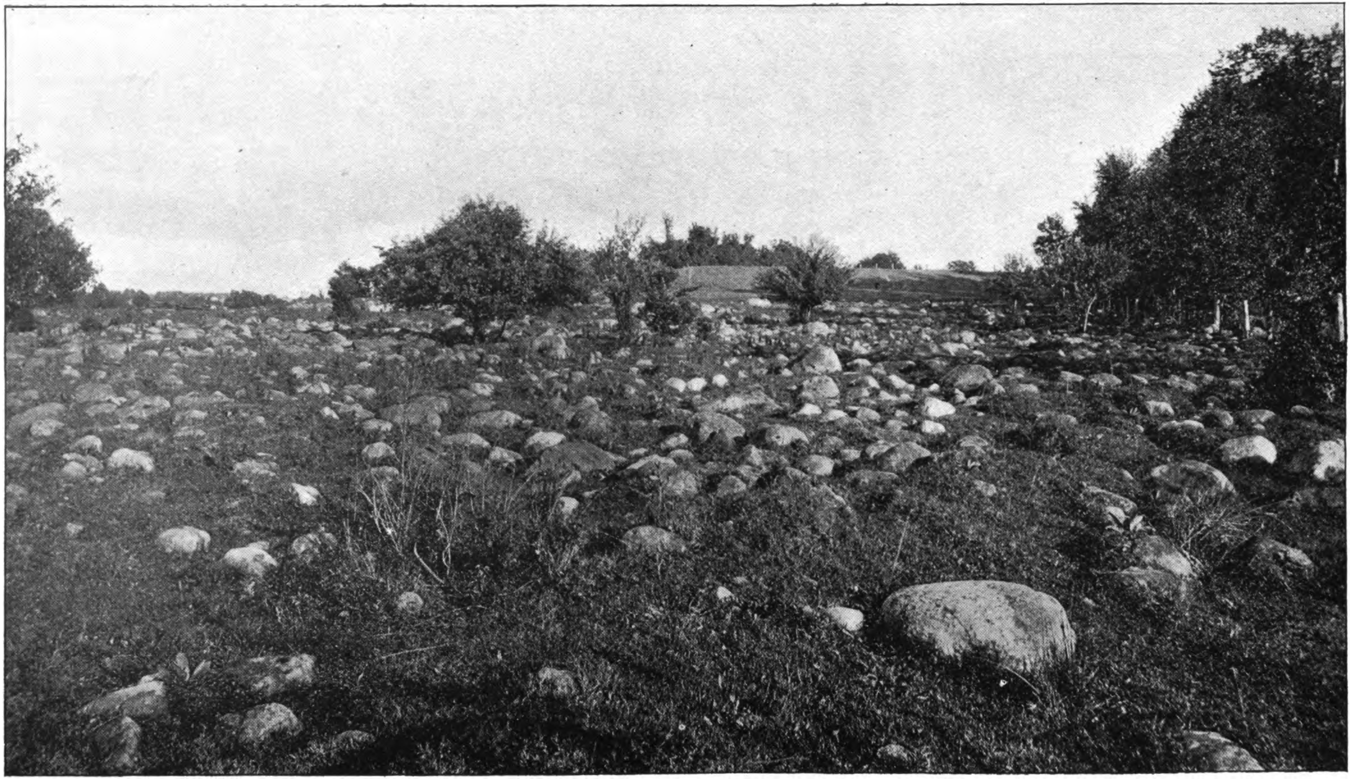


H. L. Fairchild, photo.

SHORE OF LAKE IROQUOIS

Three bars, ½ mile south of Adams. Looking s. 10° e. from the middle bar. (Compare pl. 11)

Plate 13



H. L. Fairchild, photo.

SHORE OF LAKE IROQUOIS

Wave-cut cliff in background; boulder-strewn floor of lake in foreground. 3 miles south of Adams N. Y. Looking s. 20° e.

The expectation of finding a repetition of the 27 foot interval both north and south, or of a space corresponding to it, is not fully met. Northward such interval is wanting except in profile 25, which has two groups of bars, the interval between the crests of the two groups being 37 feet. On the south the next profiles (nos. 13, 14) have a clear interval of 35 feet, which is too great; but profiles 5 to 12 do suggest a northwardly increasing interval in accord with the Adams bars (nos. 15 to 17) and with no. 25.

These figures of the third column of the table give the best showing that can be found for a northward increasing interval between the bars. Taking profiles 5 to 12, 16 and 25, an increase of about 1 foot a mile can be figured out. But this omits from consideration the profiles with a regular succession of bars, as nos. 4, 18, 21 and 24; also those which show no lower bars, though the range is sufficient, as nos. 2, 3, 22 and 23. The negative evidence seems quite as strong as the affirmative, specially since the latter rests only on a few selected profiles.

If there had been a spreading apart of the two upper bars toward the north of 1 foot to the mile, it would seem as if the spreading throughout the whole range of the bar formation should certainly be evident in column 4 of the above table. The evidence here is decidedly negative. The best that can be said regarding the suggestion of northward differential uplift during the life of Lake Iroquois is that it is not yet proven.

Time of land warping

The vertical distance between the upper and the lower bars, 35 to 40 feet, is supposed to be more than the depth of water limiting the formation of sandbars, this depth being taken as about 30 feet. The inference is that the great vertical range of the bars was produced by subsidence of the water level. The distribution of bars at all levels throughout the vertical range suggests a slow subsidence. It seems probable that the lowering was caused by the down-cutting of the outlet of the lake at Rome N. Y., and not by the tilting of the basin. The warping of the region has apparently occurred since the extinction of Lake Iroquois, or else the movement was so slow that it was not positively registered in the Iroquois beaches. Any tilting during the life of Lake Iroquois was at the most only 1 foot a mile, or one fifth of the entire warping.

The maturity of the shore line is so far advanced that it would seem to have required at least a few thousand years. The present rate of northward differential uplift of the area of the great lakes has been recently estimated by Mr Gilbert as equal to .42 foot in 100 miles in 100 years. At this rate it would take 10,000 years to produce in the Richland-Watertown stretch of shore line (26 miles) a deformation of merely 11 feet, and at least 12 times as long to produce the deformation which actually exists.

Conclusion

As the result of this study, two conclusions appear reasonable. They are: 1 The warping of the eastern end of the Ontario basin has occurred mostly, if not entirely, since the extinction of Lake Iroquois, as the shore seems equally tilted.

2 The large amount of tilting considered in connection with the usual estimates of post-glacial time (10,000 to 50,000 years) would indicate that the rate of deformation has been much greater than the present rate, at least for the local area.

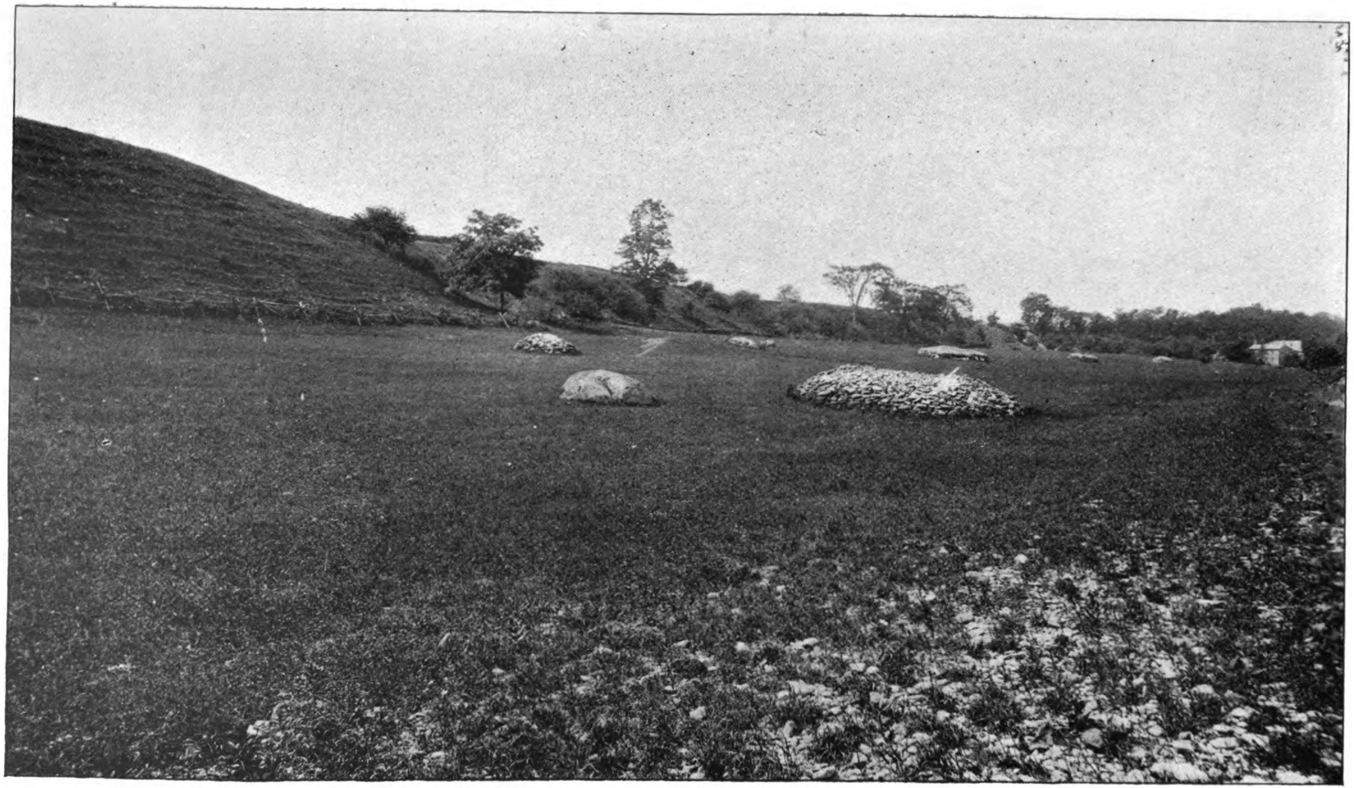
2 SYRACUSE-ONEIDA DISTRICT

General statement

In recent publications (*see* p. 105 for references) the writer has described the remarkable channels in the region southeast and east of Syracuse, which were produced by the eastward escape of the glacial waters from the Onondaga, Butternut and Limestone valleys. The highest of these ancient channels were probably cut by the escape of local waters held by the ice sheet in the deep valleys now occupied by the streams named above. The lower and more capacious channels were certainly made by the great rivers which drained the vast glacial lakes that fronted the ice sheet far westward across the Ontario, the Erie and the southern Huron basins. The general history and description of

Plate 14

To face p. r112

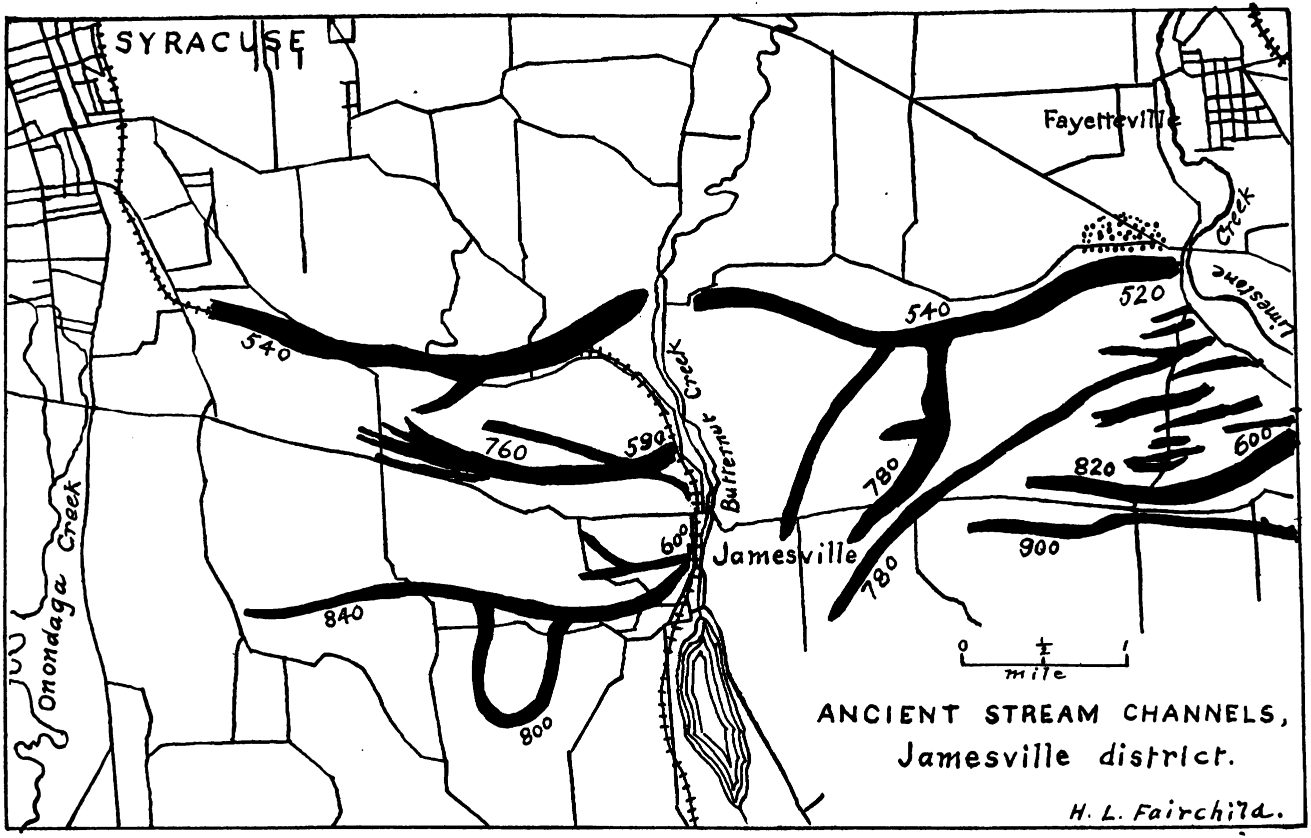


H. L. Fairchild, photo.

SHORE OF LAKE IROQUOIS

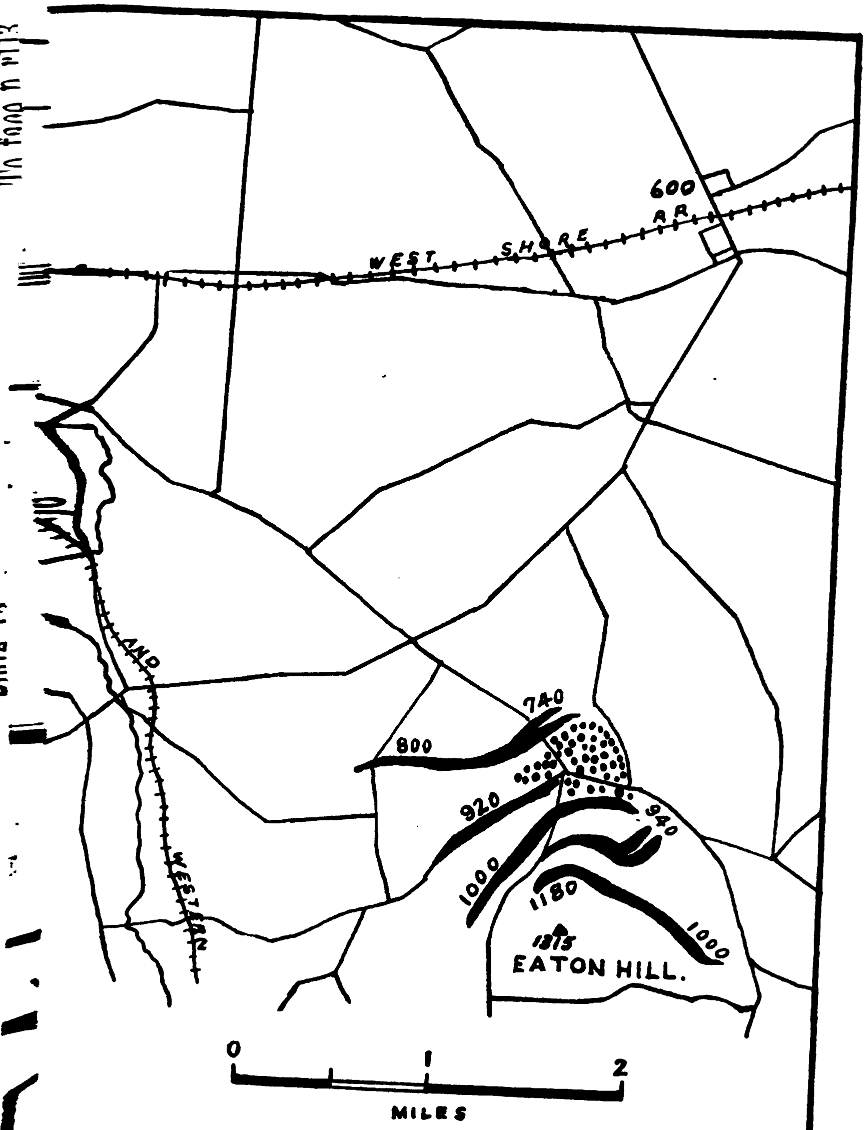
Bar in front of cliff, 7 miles south of Watertown, and ¼ mile north of Talcott's corners. Looking southeast

Plate 15



ANCIENT STREAM CHANNELS,
Jamesville district.

H. L. Fairchild.



GLACIAL STREAM CHANNELS IN CENTRAL NEW YORK

By H. L. Fairchild.

front by the water flowing between the higher those great glacial lakes, named Warren, Dana and hyper-Iroquois waters, has been given in the writings referred to above. During the summer of 1900 several very interesting series of high channels, cut by the earlier and local waters held at high levels in the valleys east of Manlius and Fayetteville (Limestone creek) have been mapped as far eastward as Eaton hill, 6 miles southeast of Oneida.

At this time it is impossible to write a full and detailed description of these remarkable and interesting phenomena and of their correlations, since some details are not yet studied, and their relations to the primary outlets across the divide to the south have not been determined by personal observation. A general description can properly be given now, with some illustrations.[1]

Valleys and local lakes

A glance at the accompanying sketch maps (pl, 15, 16) will show the following larger creeks flowing northward, in successive order toward the east: Onondaga creek, flowing through Syracuse; Butternut creek, flowing through Jamesville; Limestone creek, flowing through Manlius and Fayetteville; Chittenango creek, flowing through Chittenango; Cowaselon creek, flowing through Merrillsville and Hobokenville; Oneida creek, flowing through Oneida.

These streams all lie in deep valleys of preglacial origin, and were the sites of glacial lakes during the time when the front of the ice sheet was slowly receding northward over the region. Between the valleys are high ridges of Silurian and Devonian strata covered with a veneer of glacial drift. The ridges end quite abruptly on about the parallel of Chittenango.

With this suggestion of the topography, the reader can readily understand the effect produced on the drainage by a huge dam of glacier ice extending east and west athwart the north-sloping valleys and ridges. The waters from precipitation and from the melting of the glacier would be impounded in the open portion of the valleys south of the ice front. Primarily these local glacial lakes had their outlets across the divide at the head of each valley into some course of southern drainage, and this disposal of the surplus waters continued till the receding ice front uncovered passes across the crests of the ridges which were lower than the cols or outlets at the valley heads, and which led in a direction permitting free and final escape of the overflow.

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[1] The writer desires to express here his hearty thanks for and appreciation of the help given him in the study of this district by two gentlemen of Cazenovia, J. H. T. E. Burr and Robert T. Hubbard. Their interest and assistance in the work were both an advantage and a pleasure.

The glacial lakes which occupied the Onondaga and Butternut valleys have been described in the former writings.[1] It was the intention to examine during 1900 all the low passes or cols across the divide at the heads of the several valleys east of Butternut valley, and to study the history of the glacial waters held in the valleys. This plan was not carried out except for the Limestone valley and the Cazenovia valley, the latter lying eastward of and connected with the former. The data relating to these valleys and their glacial lakes will be presented here.

In order to fully understand and appreciate the geologic features to be described, the reader should have before him the Cazenovia sheet of the New York state topographic map, on which are located all the places and geographic features referred to in the following description.[2]

Limestone and Cazenovia valleys

Divide and outlets. The line of water parting between north-flowing and south-flowing waters passes south of Erieville, on the east edge of the map. Running west southwest over the hills, it crosses the New Woodstock valley on a moraine filling, 1½ miles north of Sheds Corners. It then passes west over the summits of three high hills, and then makes a sharp turn to the south around the Deruyter reservoir. The line then trends west of north over Arab hill, and Stockham hill, and runs 3 miles farther north around the head of the stream which flows into Carpenter pond.

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[1] Geol. soc. Am. Bul. 10:57–64; Am. jour. sci. 7:251–54.

[2] Any published sheet of the New York topographic map may be obtained by sending 5 cents to the director U. S. geological survey, Washington D. C.

There are four low passes across this divide to which reference will be made. The altitudes are shown by the contour lines of the map to within at least 20 feet.

There is a low notch or col 2 miles southeast of New Woodstock village, and over a mile north of Sheds Corners. The lowest point is at the west side of the moraine, with a map altitude of 1360 to 1380 feet. The Elmira, Cortland and Northern branch of the Lehigh Valley railroad takes advantage of the lowest point, but makes a cutting at the summit. There is no defined channel across the col, from which we conclude that it did not carry the overflow of any large lake. Theoretically, however, judging from the topography, it seems likely that a small lake, perhaps 3 miles long, existed in the valley north of the moraine, covering the site of New Woodstock. When the receding ice front exposed ground northwest of the village, at about 1360 feet, the small and short-lived New Woodstock glacial lake was drained into the larger lake now to be described.

One mile south of Deruyter reservoir are two passes across the divide separated by a hill. The map makes the altitude of the eastern pass 1300+ feet and of the western, 1320 feet, but an aneroid measurement makes the latter pass the lower. The western col is an extensive swamp, still partly in forest, with definite channels leading south. The northwest-southeast road, 2 miles south of the reservoir, crosses the outlet channel a mile below the summit, at a point where it has an eastward loop. The eastern col shows less action of flowing water. It carries the state ditch which diverts into the reservoir water that naturally had southern flow. A small, local, glacial lake, about 4 miles long, which we may call the Deruyter lake, had its outlet by one or both of these passes till the ice dam had receded past the north end of Arab hill.

The lowest pass across the divide and the one which was the chief outlet of the glacial waters, is at the north end of Arab hill, 4 miles west of New Woodstock and 2 miles south of Delphi. It leads west toward Fabius and has a map altitude of 1280+ feet. The col is an open valley, cleared of forest, and shows plainly the lengthwise channeling by flowing waters. 1 mile west, where crossed by a north and south highway, the river channel is well formed, about 30 rods wide and 20 to 30 feet deep, with definite banks. Pl. 17 and 18 reproduce two photographs of the channel at the road crossing.

This outlet which we may call the Fabius outlet, since it leads toward that village, some 3 miles away, remained the outlet of a large glacial lake (Manlius-Cazenovia lake) for a long time. When the glacier front receded some 11 miles, it uncovered a lower pass, at Perryville (Blakeslee), about 5 miles northeast of Cazenovia which was the first of a series of channels giving eastward escape for the waters (*see* p. 124).

Moraines. The heaviest and most conspicuous massing of moraine drift is at the head of the Limestone valley proper, 1 mile south of Delphi village. A southward continuation of this moraine stretches about 3 miles to the foot of the Deruyter reservoir. Another small valley moraine has already been mentioned as constituting the divide in the valley south of New Woodstock. The higher, or hill ground does not carry heavy drift, but the lower ground holds considerable moraine, or kame drift. Most of the surface between Cazenovia and New Woodstock is morainal, and that which lies below 1300 feet is of a rounded, smooth and subdued form characteristic of moraine deposits laid down under water. This area can be well seen from the Lehigh Valley railroad.

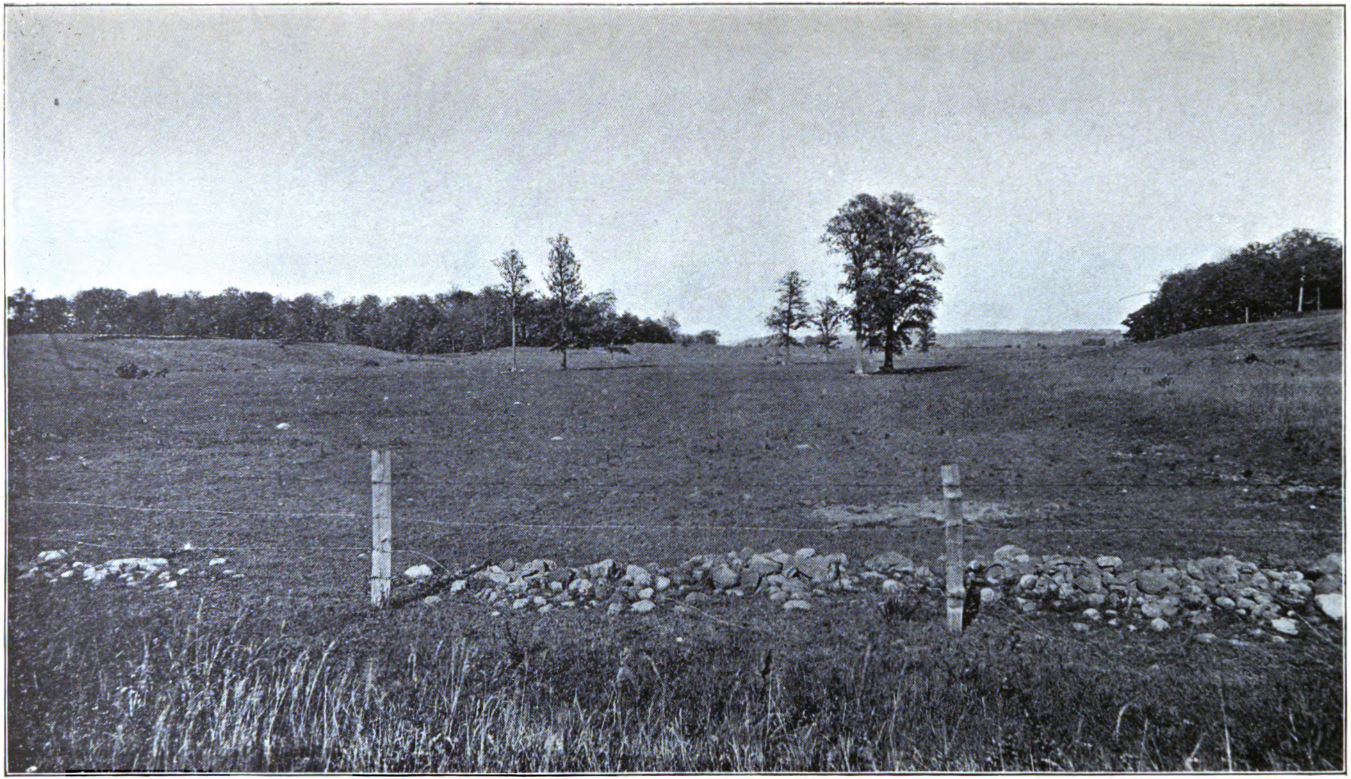
Special features. In the northern part of the area of the Cazenovia sheet the drift is mostly in the form of drumlins, specially on the higher ground. West of Cazenovia lake the ridge which divides the valley from the Limestone valley is cut by a deep notch, plainly shown on the map. The altitude of this notch is about 1270 feet, and it must therefore have held a strait which connected the two branches of the glacial lake.

Manlius-Cazenovia glacial lake

Geography. The glacial lake in the Limestone valley filled the valley from Deruyter reservoir as far northward as Manlius, a

Plate 17

To face p. r116



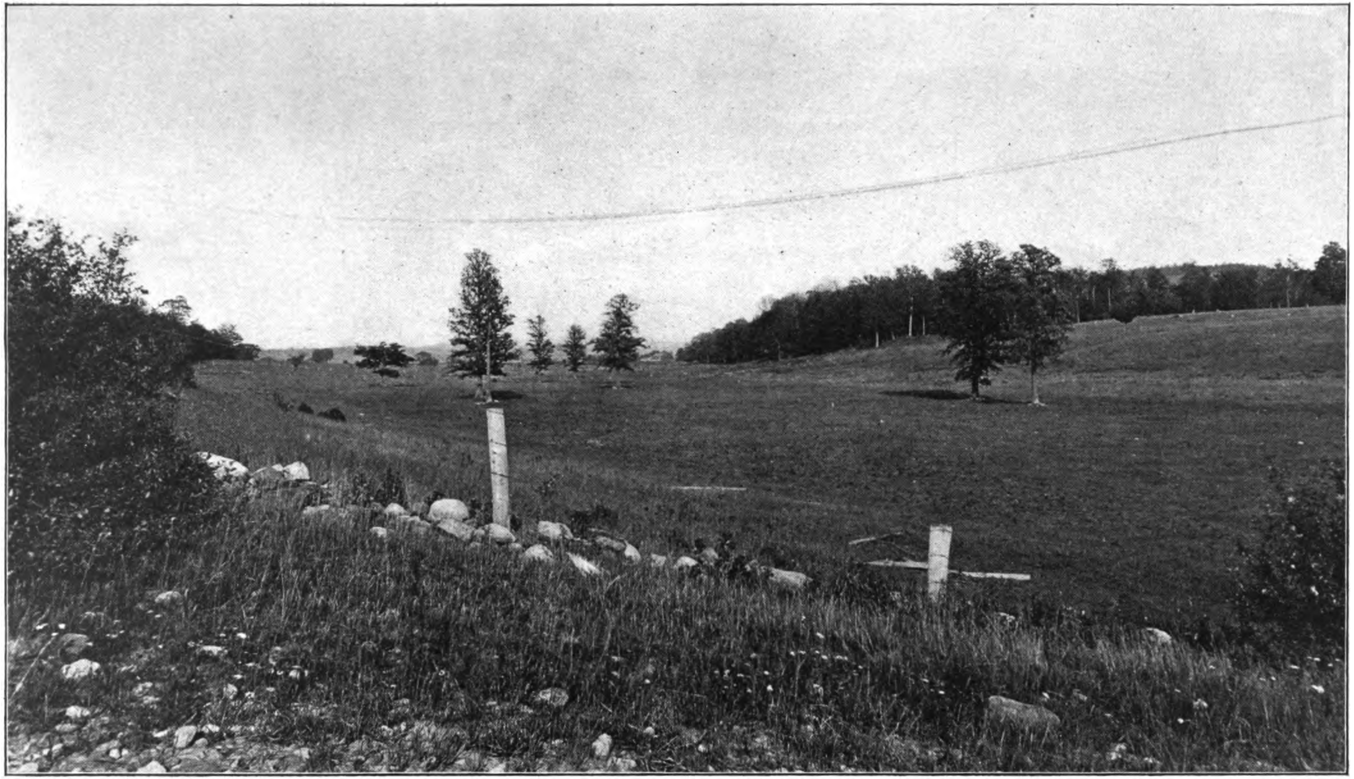
H. L. Fairchild, photo.

FABIUS CHANNEL; OUTLET OF MANLIUS-CAZENOVIA GLACIAL LAKE

View looking upstream (east) ¾ mile from intake or head of channel. (Compare pl. 18)

Plate 18

To face p. r116

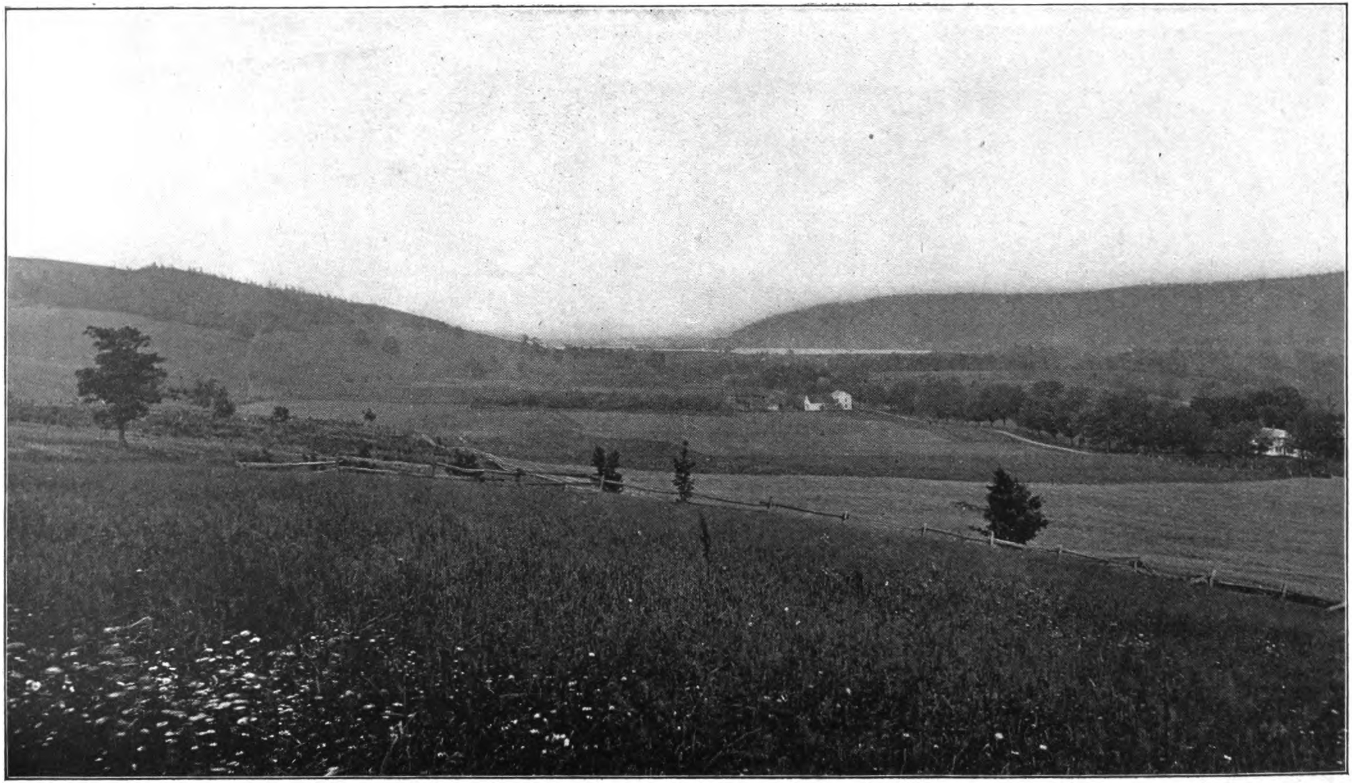


H. L. Fairchild, photo.

FABIUS CHANNEL; OUTLET OF MANLIUS-CAZENOVIA GLACIAL LAKE

View looking upstream (southeast) ¾ mile from intake. (Compare pl. 17)

Plate 20

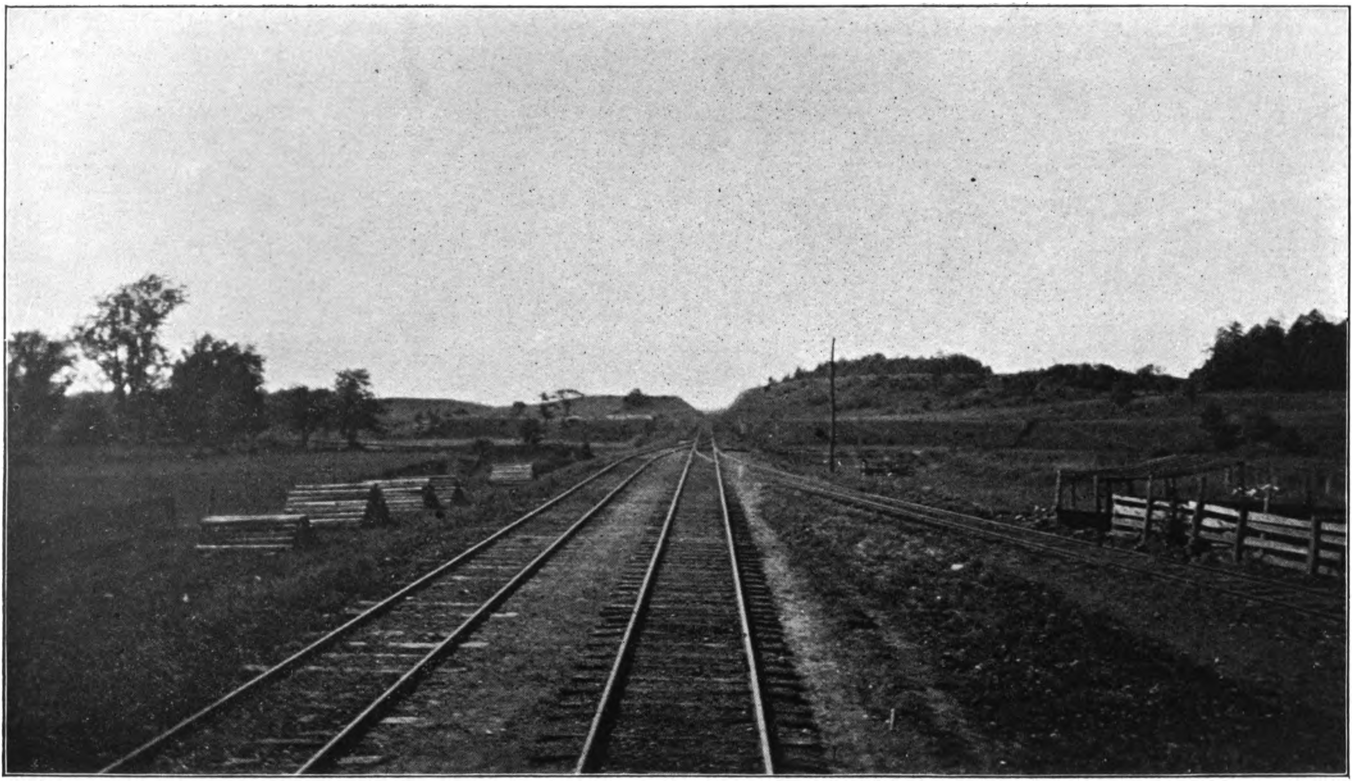


H. L. Fairchild, photo.

HEAD OF LIMESTONE VALLEY

Site of Manlius-Cazenovia glacial lake. View looking south over DeRuyter reservoir from near Union Corners

Plate 21



H. L. Fairchild, photo.

DELTA PLAIN OF MANLIUS-CAZENOVIA LAKE

View of eroded edge, 40 rods north of New Woodstock station distance of about 15 miles. Its breadth, in this valley, was only 2 or 3 miles, but it had a branch or fork on the east which filled the shallow valley of Cazenovia and the narrow, deep valley of Chittenango creek, thus making a lake of considerable area but irregular shape (pl. 20).

All the overflow of these glacial waters was contributed to the south flowing Tioughnioga creek; those of the New Woodstock phase to the west branch of that creek, those of the Deruyter phase to the middle branch, and those of the larger, more important Manlius-Cazenovia lake to the west branch. During the time which we are considering the Tioughnioga was a large river, carrying to the Susquehanna the abundant waters from the melting of a long stretch of the glacier, and deeply filling portions of its ancient valley with detritus from the glacial drift.

Deltas. The most conspicuous delta in the basin of the Manlius-Cazenovia lake is at Union Corners, 1 mile west of Delphi station on the Lehigh Valley railroad. A broad delta was built here by the New Woodstock creek, with a summit plateau of 1280 feet altitude. The village of New Woodstock stands on a delta plain built in the lake by the united action of the two branches of the creek. Pl. 21 is a view of the eroded edge of the upper level of the plain north of the village.

Remnants of other deltas may be found where streams poured down into the ancient lake. Other evidences of standing water may also be frequently seen, such as leveled stretches, produced by the filling of shallow places by land wash or by peaty accumulation. Hints of wave cutting will be rare. The evidences of standing water should be looked for somewhat above the 1300 contour at the north edge of the quadrangle, and somewhat below this contour at the middle of the sheet.

Differential uplift. The reader should not forget that the map contours do not show the precise altitude of the region at the time of the ice retreat, as since that time there has been a northward uplift or tilting of the earth's surface over all the area of the Laurentian basin. The amount of tilting in this region is not yet determined, but it is probably two or three feet to the mile and possibly more. Consequently today the plane of the ancient lake surface is not level, but rises to the northward. That plane was determined by the Fabius outlet. If the bottom of that channel be taken as 1280 feet, and if we assume the depth of water over the intake as 20 feet, we will have 1300 feet as the altitude of the lake surface at that point. The corresponding plane at Cazenovia is now at a higher level, perhaps about 1320 feet, depending on the unknown rate of uplift. At the parallel of the Perryville outlet the plane would be still higher.

Variable elements. The student of these phenomena will need to be on his guard against several sources of error. In correlating outlet channels with delta terraces or other static water phenomena, the following points must be kept in mind. 1) Downcutting of the outlets. The first flow of water over any of the long-lived channels must have been at a level somewhat higher than the later flow, more specially if the channel was in drift or soft material. 2) The depth of water over the wasteweir, or head of the channel, is to be considered in determining the hight of the lake surface. 3) The hight of water surface was subject to considerable variation, as in modern lakes. This variation would be greater in the smaller lakes, where the difference between the winter and summer melting of the glacier would be a larger proportionate factor. 4) The deltas usually have several levels or terraces, caused partly by changes in the lake level, but specially by the lowering of the water surface as the lake was slowly drained away. 5) In the southern ends of the valleys terraces may be found to correlate with the two or more outlets. 6) The relation of the delta plain to the water surface varies somewhat according to the coarseness of the detritus and the rapidity of its deposition. The head of the delta should be a few feet above the water level, and the point or front under the same level. 7) Failure to find expected phenomena does not always prove their nonexistence. And the positive nonexistence of features which are theoretically expected does not necessarily prove the absence of the agency. Shore phenomena, in particular, are liable to be weak or even wanting where we know that deep waters stood for ages. 8) Allowance must be made for the erosion or weathering, since the producing agencies were withdrawn.

High channels leading east toward the Mohawk

Origin and location. During the life of the local glacial lakes described in the preceding pages the Mohawk valley was cleared of the glacier, at least sufficiently to permit free drainage to the sea, and these local valley lakes were at liberty to overflow east instead of south as soon as the passes across the ridges were opened. Such eastward flow was eventually certain, but it did not occur till the receding ice front had uncovered the north ends of the intervalley ridges, as the latter are higher than the cols at the southern ends of the valleys.

At the north point, or brow, of each great ridge we find a series of terraces and channels cut into the rock by the swift flow of escaping waters. There are six groups of these high channels, and they will be considered in order from west to east. The reader should have before him the following four sheets of the topographic map, Syracuse, Tully, Chittenango, Oneida.

1st group. The most westerly group of high channels lies at the north end of the ridge which forms the east side of the Onondaga valley, 4 miles southeast of Syracuse and close to Jamesville. They have already been described,[1] and can be located by the contouring on the bottom edge of the Syracuse and the top edge of the Tully sheets.

2d group. This group lies between Jamesville and Manlius villages, on the slope of the ridge between Butternut and Limestone creeks. The channels may be located on the same topographic sheets as group 1, and they have also been described in a general way. (References as above)

3d group. The channels of this group lie on the north slope of Eagle hill, between Limestone and Chittenango creeks, and southeast of Chittenango village. They are located on the lower edge of the Chittenango sheet, but are not well indicated by the contours. They have not been described, but will be briefly described in the following pages, along with the later groups of channels.

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[1] Geol. soc. Am. Bul. 10:54, 60–61, pl. 3, 7–9.
Am. jour. sci. 7:251, 262, pl. 6.

4th group. This group of channels lies on the north-facing slope north of the village of Perryville, and along the north and northeast slope of Cranson hill, between Chittenango and Cowaselon creeks. They form a series of interrupted scourways at different levels, and are only suggested by the contours on the adjoining lower corners of the Chittenango and Oneida sheets.

5th group. These strong channels are 3 miles south of Oneida village on the crest and north slope of West Stockbridge hill, between Cowaselon and Oneida creeks. They are fairly well indicated on the lower part of the Oneida sheet.

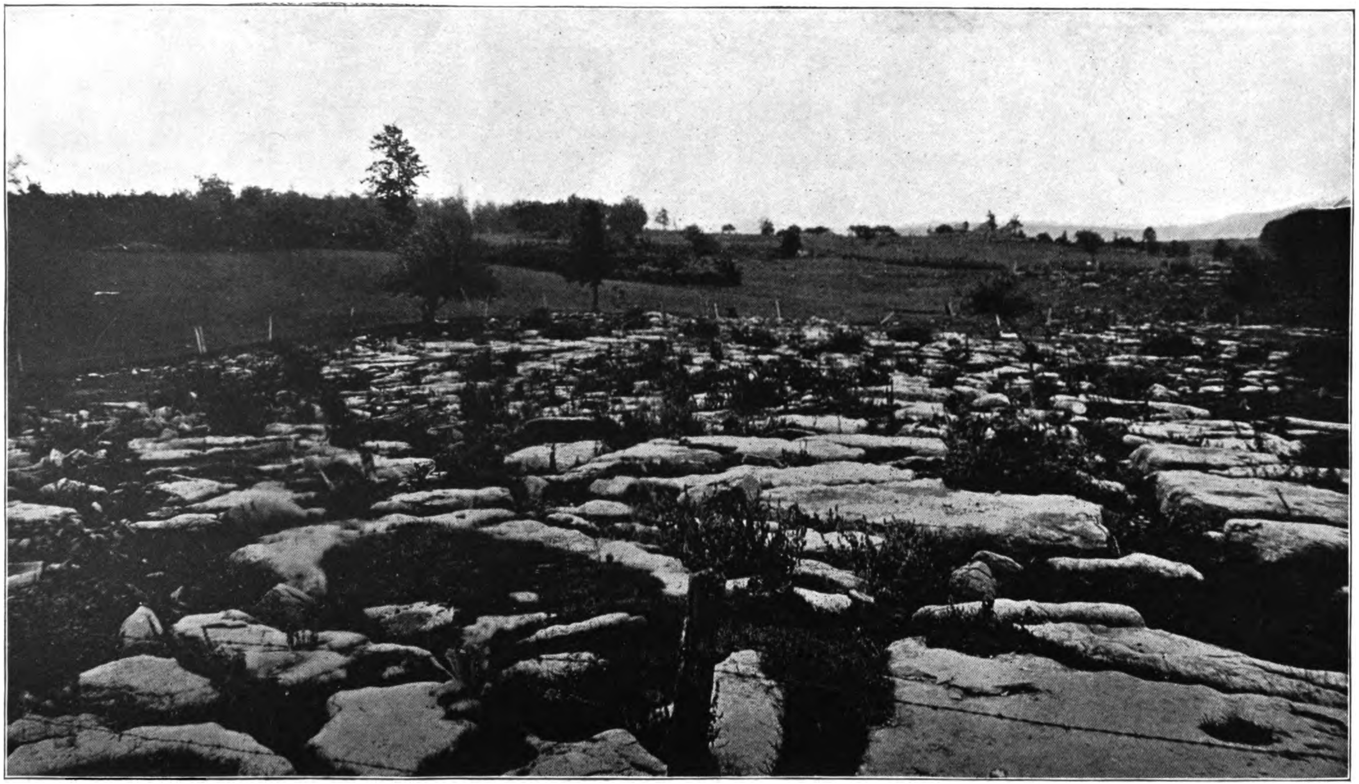
6th group. This very compact group of strong channels lies on the north brow of Eaton hill, between Oneida and Sconondoa creeks, 6 miles southeast of Oneida and 3 miles south of Vernon. This is probably the most easterly group of high channels, judging from the topography. However, the territory lying between here and the Mohawk valley remains to be studied.

Range in vertical distance. In each group the channels cover a vertical distance of several hundred feet. The highest cutting leading east must lie under the true plane of the lowest outlet to southern flow. The original difference of level may, in some cases, have been very small, and with the subsequent tilting of the land it is possible that the later, east-leading channel might now be even somewhat higher than the earlier one at the head of the valley. The correlation of these east-leading channels with the cols and south-leading channels on the divide is a subject for future study.

In the Eagle hill group the highest water course is over 1100 feet above tide, and the lower ones about 800 feet, all lying within a horizontal distance of 1 mile. The Cranson hill group ranges from 1200 down to 800 feet in 1½ miles. The West Stockbridge hill group has a greater range, from 1300 down to 700 feet in something over a mile. The Eaton hill group ranges from 1200 down to 800 feet in less than a mile.

Plate 22

To face p. r121

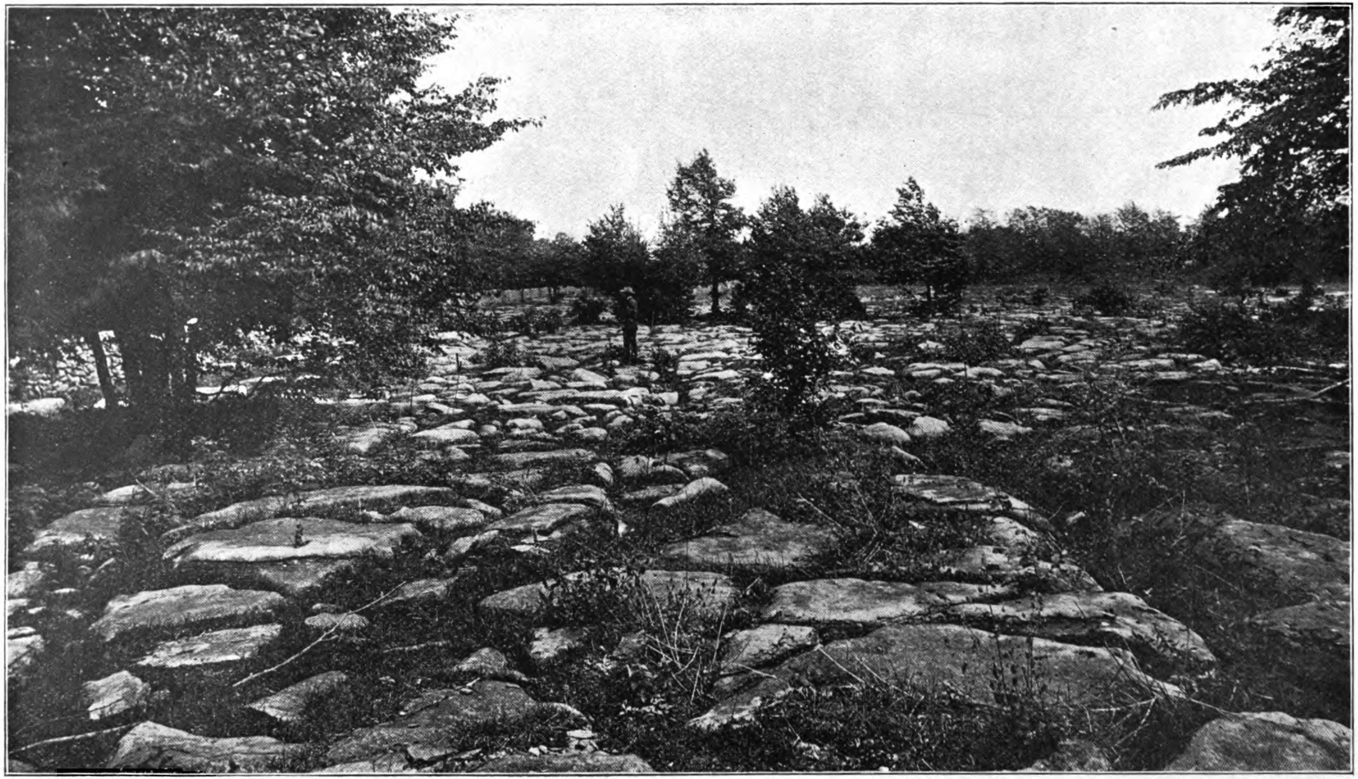


H. L. Fairchild, photo.

STREAM AND LAKE EROSION

Limestone, west side of Cranson hill, 1 mile north of Perryville. Looking southeast. (Compare pl. 23, 24)

Plate 23

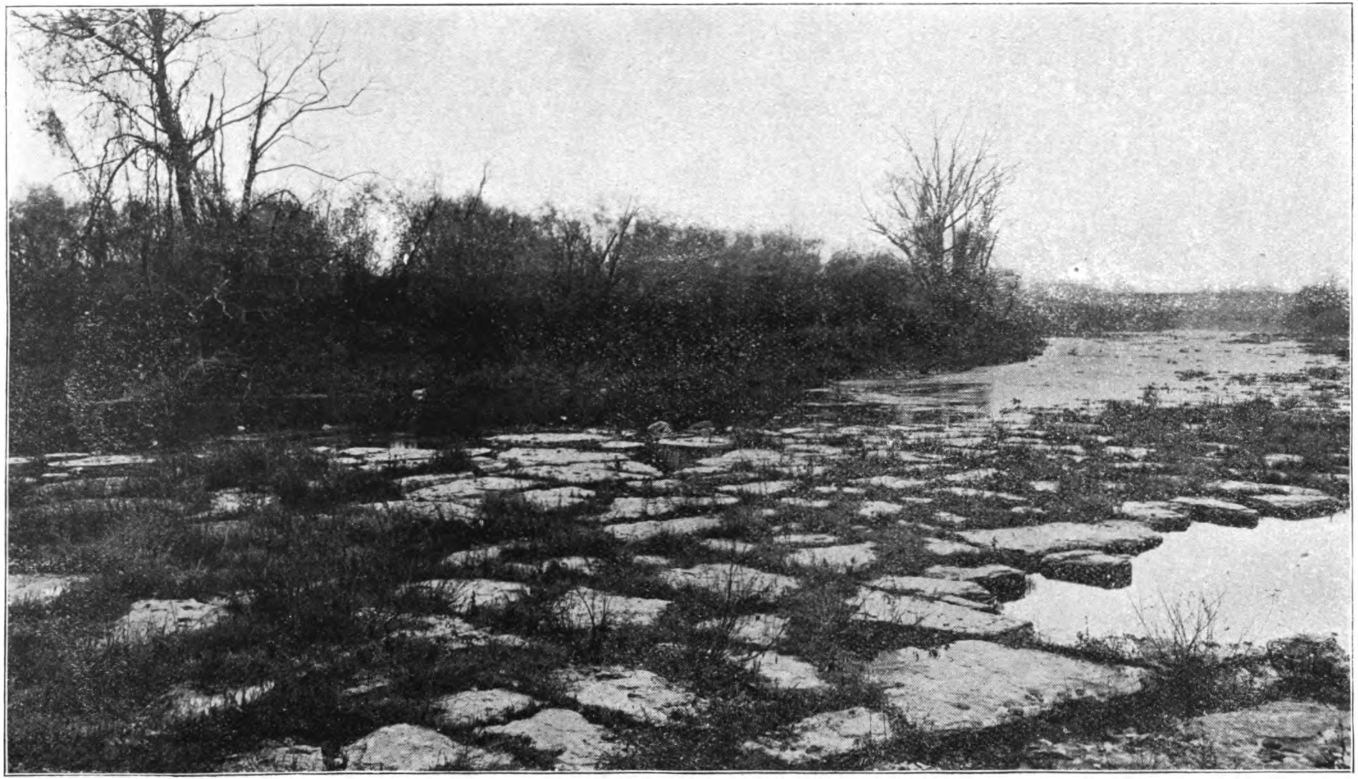


H. L. Fairchild, photo.

FLOOR OF ANCIENT RIVER CHANNEL

Limestone, northwest side of Cranson hill, 1120 feet altitude. Looking downstream, east. (Compare pl. 22, 24)

Plate 24



H. L. Fairchild, photo.

FLOOR OF LIVING STREAM CHANNEL

Limestone, bed of Cayuga creek, east of Buffalo, ¾ mile above Bellevue. Looking downstream, southwest. (Compare pl. 22, 23)

Form and character of the channels. The character of the channels depends on several conditions, of which three may be noted, namely: 1) the nature of the rock, 2) the relation of the ice front to the topography, and 3) the relation in altitude of the stream to the receiving land surface or water body. These three elements will be discussed in order.

1 The higher channels in each of these groups are mainly in the Helderberg and Corniferous limestones, while the lower channels are in the Salina shales. The highest scourways of the Eagle hill and Cranson hill groups are in Hamilton shale. This difference in the rock causes great difference in the form and size of the channels. Those in the limestone are often shallow, or only broad scourways. If deep, they usually have steep or even vertical walls, with cascades and cataracts if the underlying shale is reached. Those in the shales are relatively deep, but the walls are more sloping and smoother. The rapid weathering of the shale has cut back the walls and partially filled the channel bottoms, so as to give them a V shape, which they did not have originally. The limestone channels, on the other hand, are practically as the rivers left them, being stretches of bare rock, greatly dissolved along the joints and fissures. This solution of the limestone has often given to the scourways the appearance of a field of boulders (pl. 22–24).

2 A peculiar and interesting feature of these channels is the absence in many cases of the north bank. Those on steep slopes are sometimes only shelves or terraces cut into the escarpment. In such cases the north wall is in the air, as it was constituted by the ice which has disappeared. For a long time, centuries at least, and possibly for thousands of years, the waning ice sheet of the Ontario basin pressed against the escarpment or steep slope which formed the southern side of the basin. The waters which were held in the valleys and were escaping eastward from one lake to another were often compelled to squeeze through between the rock wall on one side and the ice wall on the other. The north ends of the high ridges are in consequence of this relationship cut into a series of steps or shelves. In the case of the West

Stockbridge and Eaton hills the notches are conspicuous profile features even at great distances. When the streams were confined in rock walls, they intrenched themselves in the rock and sometimes cut ravines of large dimensions (*see* p. 123, 124).

3 It will be understood that the cutting of a ravine or the existence of cascades and cataracts implies that the lake or land which received the overflow must have had a level below that of the tributary lake or stream by at least as much as the amount of fall. We shall make use of this principle later, in our study of the order of retreat of the ice front and of the time relation of the channels.

Lower and later channels

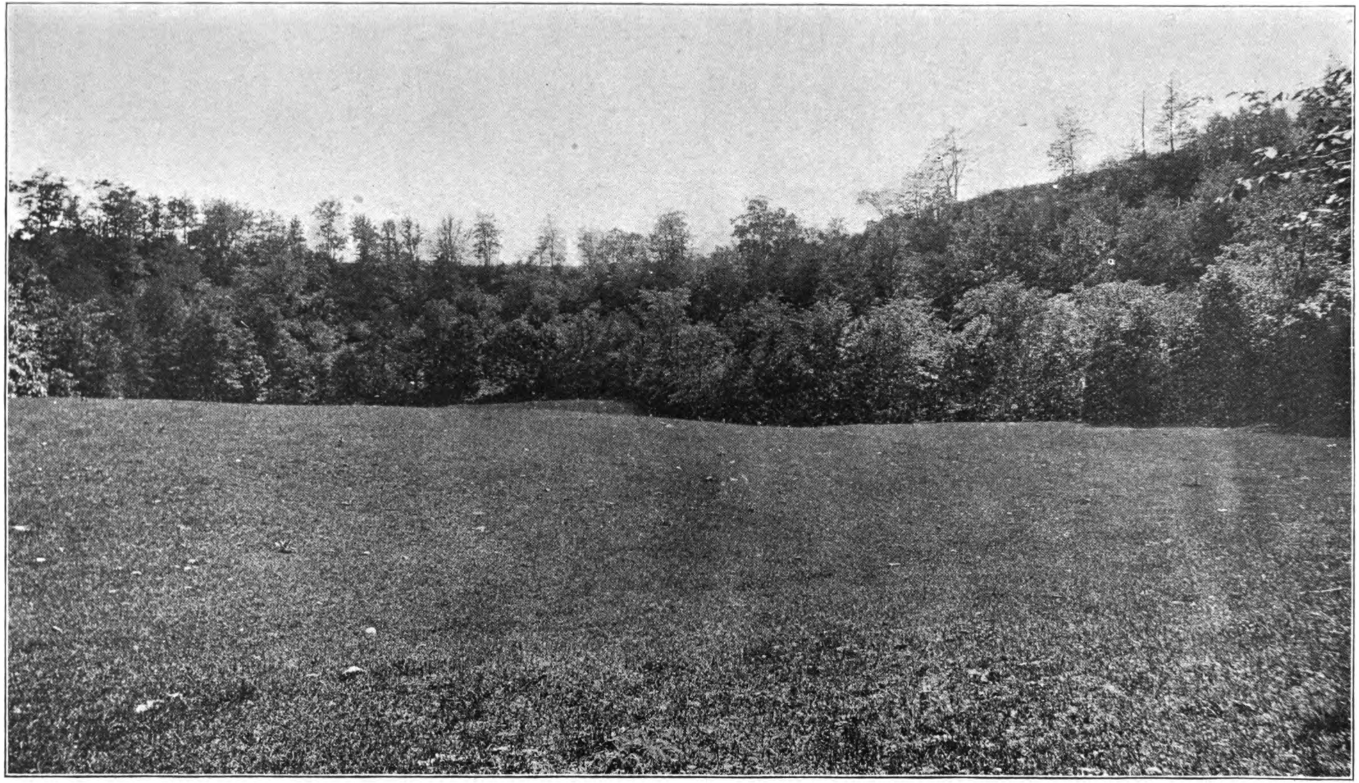
The lower channels of the first three groups were not cut by the drainage of local waters, but by overflow of the great lake Warren and the hypo-Warren waters. All the channels of the fourth, fifth and sixth groups were cut by local waters. However, north of these groups, on the lower ground, there are channels which were made by the hypo-Warren (better called hyper-Iroquois) waters. These lower channels lie north of Chittenango, at and south of Canastota, through Oneida, and toward Rome. The New York Central railroad follows here the smooth level stretches swept by the great rivers that preceded the beginning of Lake Iroquois. These later channels are outlined only by their south banks, as the rivers flowed along the ice margin which constituted their north bank. The stream-cut cliffs which formed the broken south banks of the rivers, may be seen from the New York Central and the West Shore railroads. These latest channels will be the subject of future study.

Ravines and cataracts

Some of the deeper channels in the limestone are of such form and depth that they might be called canyons. Some of them are headed by vertical cataract cliffs, the plunge basins of which in several cases now hold lakes (pl. 25–35). The largest of these gorges were cut by the hypo-Warren waters, and with their cataract phenomena were in a true sense the predecessors of Niagara

Plate 25

To face p. r122

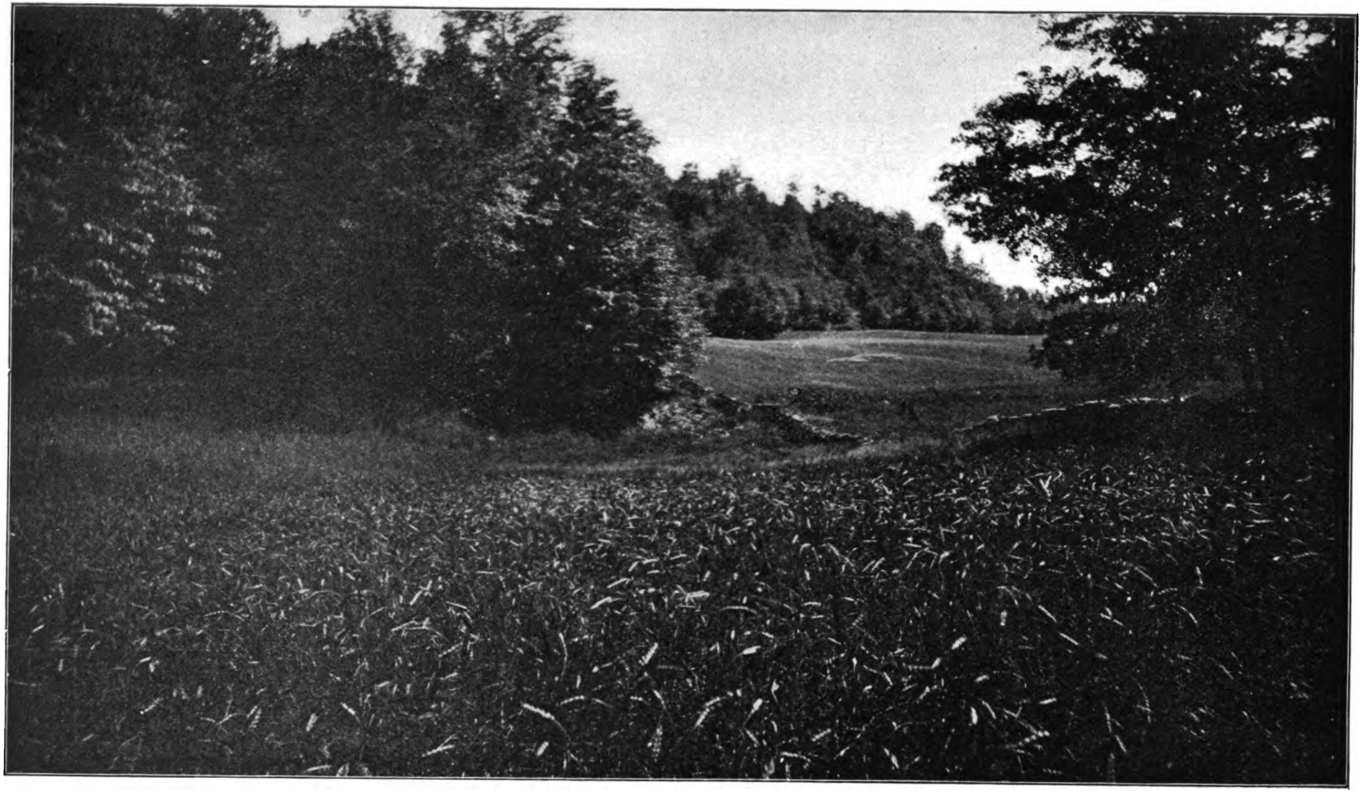


H. L. Fairchild, photo.

HEAD OF MYCENAE CHANNEL: CATARACT BASIN

1½ miles southeast of Round Lake. View shows the cataract cliff and amphitheater; looking southwest. (Compare pl. 31, 33; also Geol. soc. Am. Bul. v. 10, pl. 9, fig. 2)

Plate 26



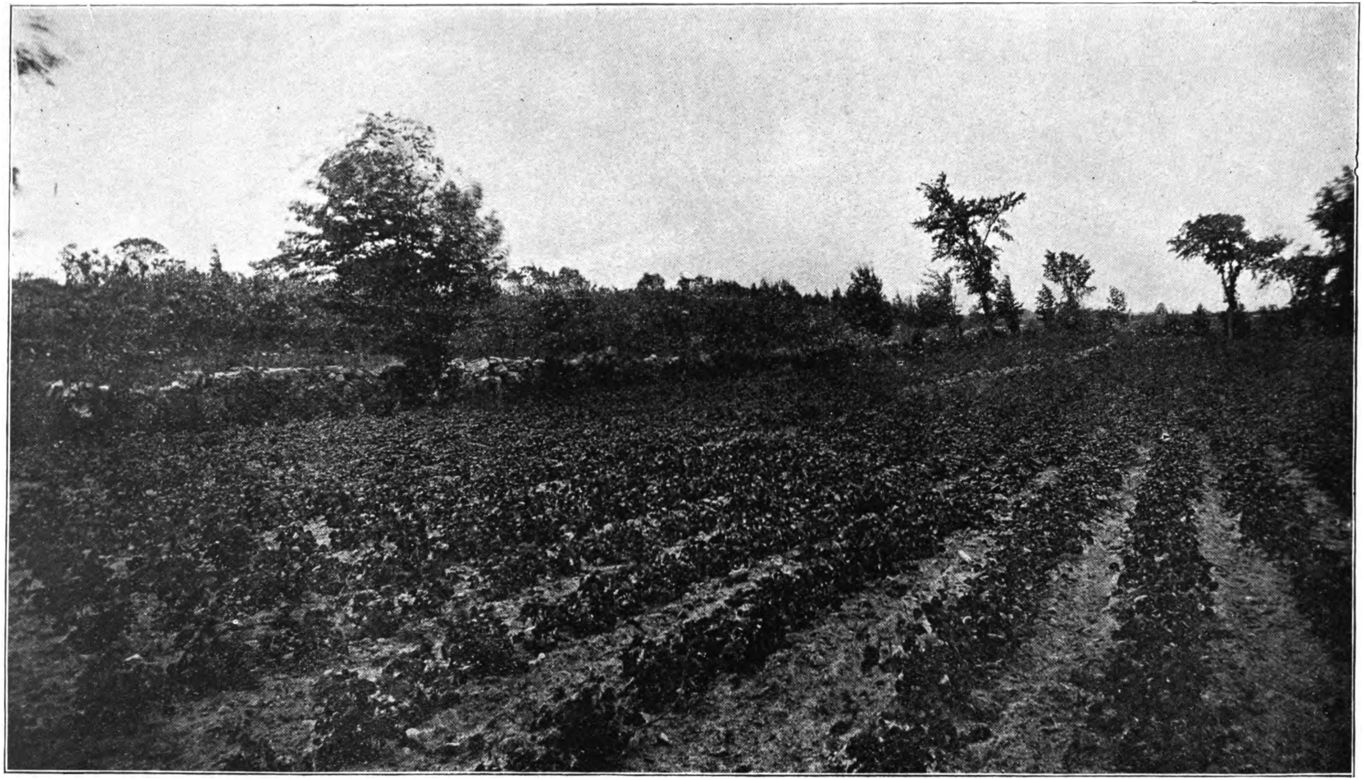
H. L. Fairchild, photo.

FLOOR OF MYCENAE CHANNEL

Looking upstream, southwest

Plate 27

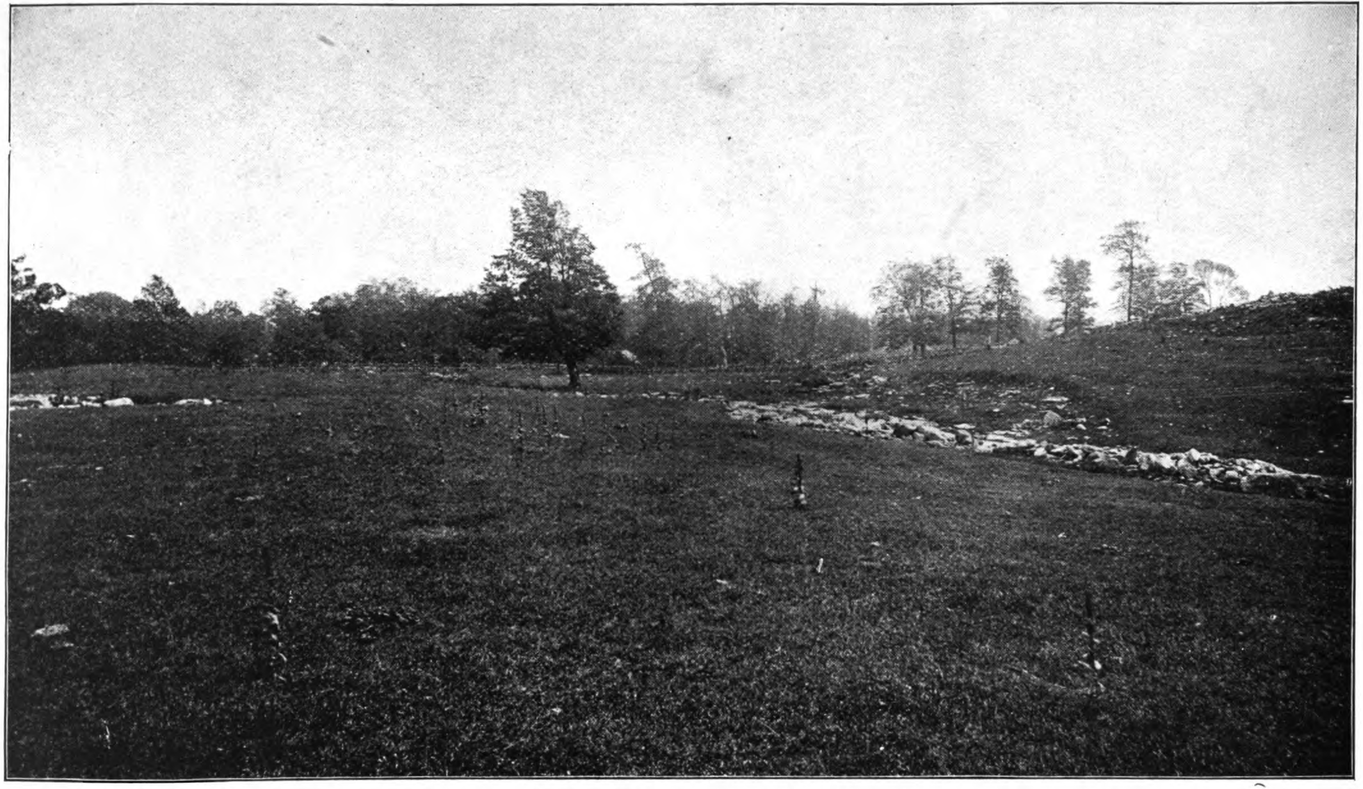
To face p. r122



H. L. Fairchild, photo.

STREAM-CUT CLIFF

Limestone, 1½ miles northwest of Eagle hill signal station, south side of highway. Looking upstream, southeast



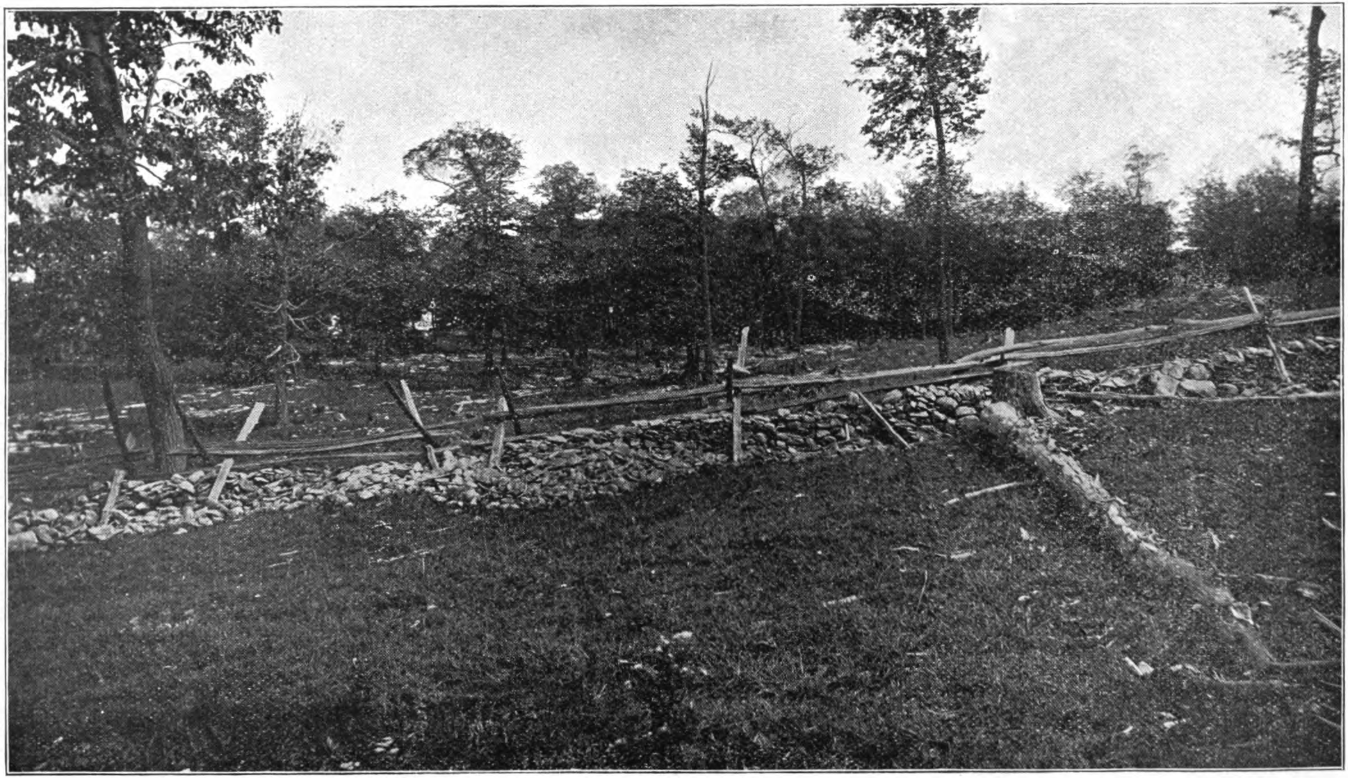
H. L. Fairchild, photo.

SCOURWAY IN LIMESTONE

2 miles southwest of Chittenango. Looking downstream, southeast. (Compare pl. 29)

Plate 29

To face p. r123



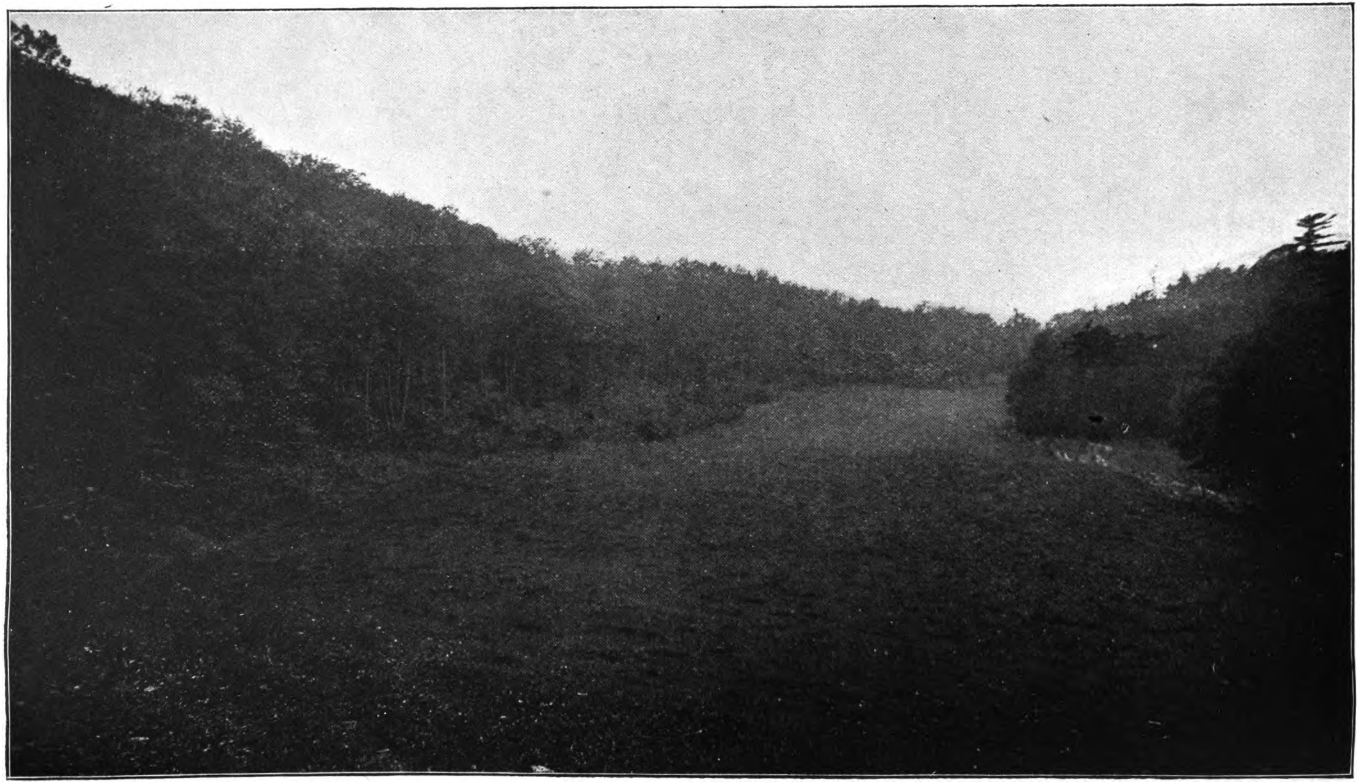
H. L. Fairchild, photo.

CHANNEL IN LIMESTONE

2 miles southwest of Chittenango. Looking downstream, east. (The same channel as in pl. 28, but farther downstream)

Plate 30

To face p. r123



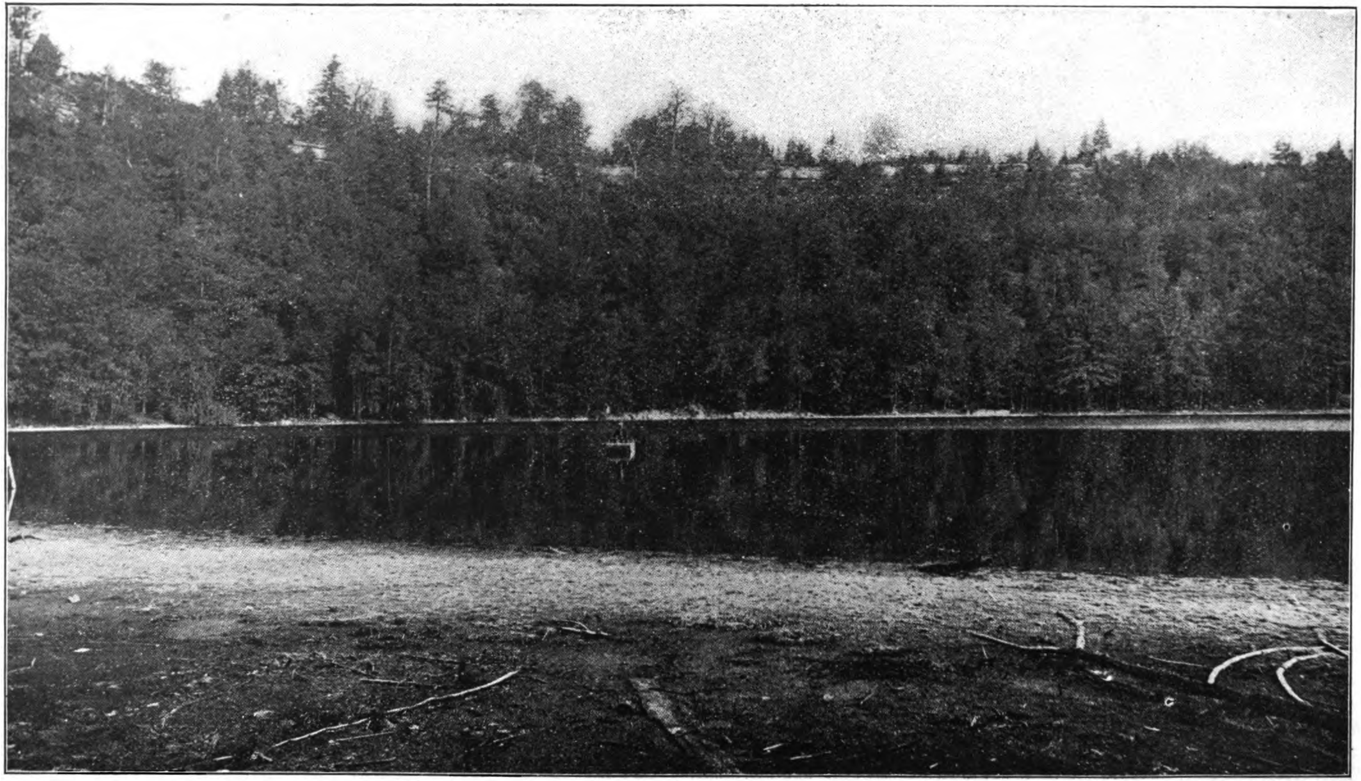
H. L. Fairchild, photo.

ANCIENT STREAM CANYON

1 mile southwest of Chittenango. Limestone. Looking upstream, west. Floor is rolling pasture

Plate 31

To face p. r123

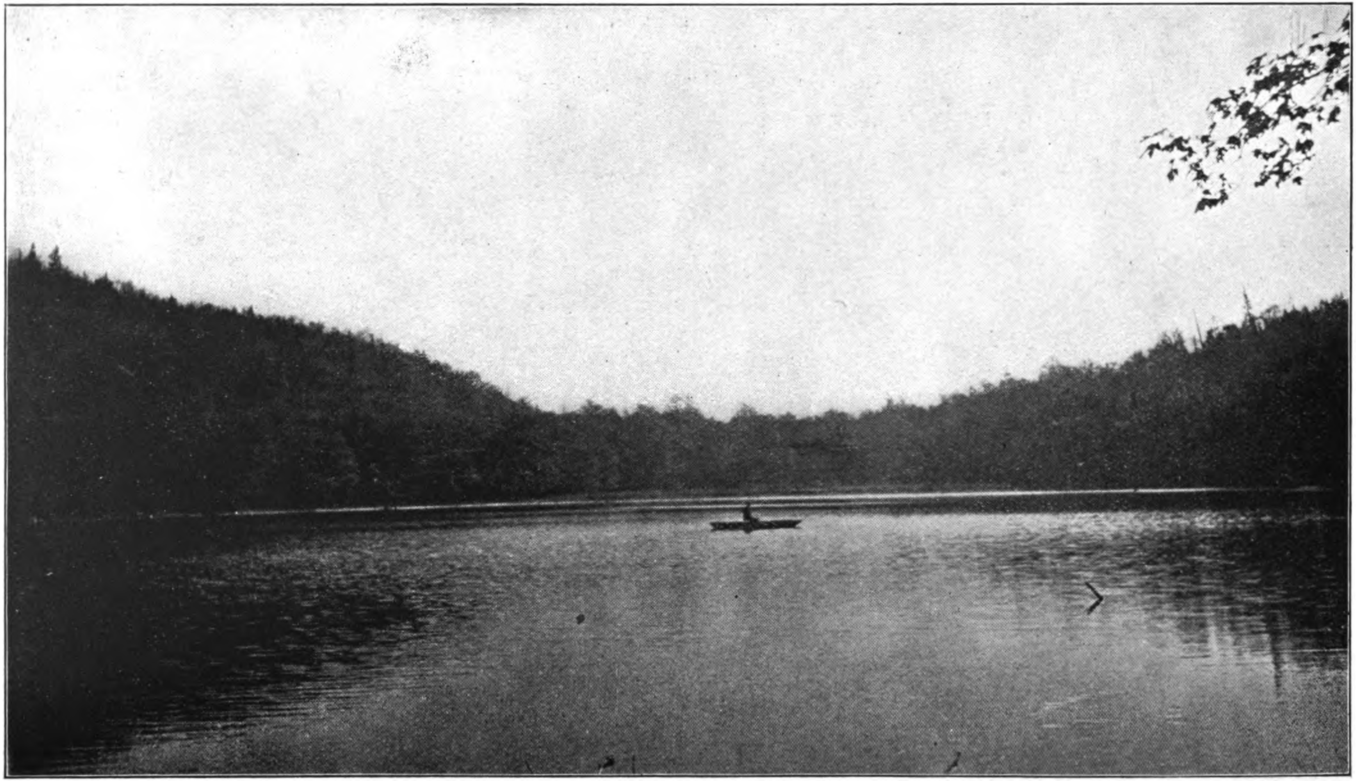


H. L. Fairchild, photo.

ANCIENT CATARACT BASIN: JAMESVILLE LAKE

1¼ miles west of Jamesville. Looking n. 20° e. across the amphitheater. (Compare pl. 32; also Geol. soc. Am. Bul. v. 10, pl. 9, fig. 1)

Plate 32



H. L. Fairchild, photo.

ANCIENT CATARACT BASIN: JAMESVILLE LAKE

1¼ miles west of Jamesville. Looking e. 10° s., down the canyon. (Compare pl. 31) (*see* p. 126). They have been briefly described, mapped and illustrated in former writings (*see* p. 105 for references).

Among the channels described for the first time in this paper are several of ravine character headed by cataract cliffs. A very interesting ravine heads 3 miles east of Jamesville and about 2 miles southwest of Manlius, with a cataract cliff about 125 feet high and an amphitheater about 50 rods across. The bottom of the ravine is a smooth meadow with two levels. The upper level is about ½ mile long, the surface being a perfectly smooth floor of fine detritus. The lower end of this meadow drops off abruptly 20 feet to another meadow, about 20 rods wide and ½ mile long, opening to the valley of Limestone creek, about a mile from Manlius village. This ravine is indicated by the coutours on the upper adjacent corners of the Tully and Cazenovia sheets. The walls are nearly vertical and in limestone. The manner in which the channel was filled so as to produce the smooth meadows has not been investigated, but the pile of rock rubbish which forms the step from the lower meadow to the upper meadow suggests a damming at that point, and a filled lake above it. This gorge was probably cut by the hypo-Warren waters, as the altitude at the crest of the fall is under 800 feet, and the mouth of the channel is under 600 feet. We will name this the Manlius gorge.

North of the Manlius gorge and west of the village, the east-facing escarpment is tremendously cut and gullied by the floods. Evergreen lake (p. 127) lies in a plunge basin excavated by these waters, and a dry basin lies a quarter of a mile south of Evergreen lake. Farther north is the large High Bridge, or White lake, channel, which has been described in former writings.

The north face of Eagle hill is all stream-swept, from 1100 feet down, while the eastern slope is trenched with ravines (pl. 28–30). Two notable gorges occur along the north side of the road leading east to Chittenango village. The larger of these is about 1 mile from the village, and near the junction of a road from the south (pl. 30). A large ravine with cataract head occurs northwest of Eagle hill, described in earlier writings as the Mycenae channel (pl. 25, 26). This belongs with the lower or Warren series.

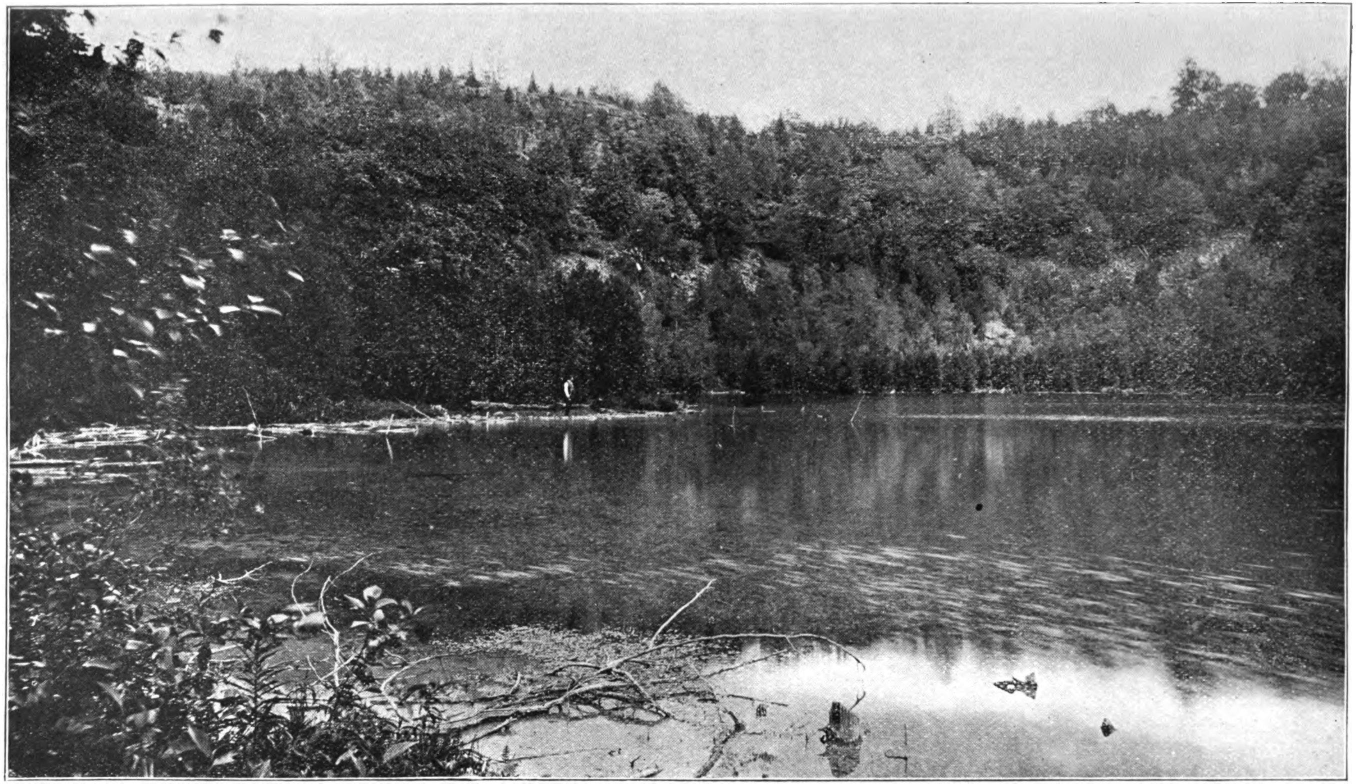
The highest of the Cranson hill channels lies so far southwest of the main series as to belong to a distinct set. It is the first eastward outlet of the glacial waters in the Limestone and Cazenovia valleys, and has been referred to above (p. 116). It lies ½ mile southwest of the village of Perryville, but has been overlooked by the topographers and is not indicated by the contours. It makes, however, a distinct notch in the ridge and at its mouth is a conspicuous delta, near the village. The channel is in shale about ½ mile long, 100 feet deep and 175 to 200 feet wide at bottom. The delta is 80 to 100 feet high, with abrupt face toward the village; it covers several acres, with two levels. West of north of this channel are other scourways, at intervals down to perhaps 900 feet. These channels are cut across a minor ridge lying between Eagle and Cranson hills and were formed at the front of a lobe of the glacier which extended southward up the Chittenango valley.

The channels of the Cranson hill series begin about a mile north of Perryville, at an altitude of 1250 feet, and form a remarkable succession of shelves and trenches in the limestone. The highest and earliest channel lies ¾ of a mile northeast of Perryville. This outlet determined the water level of the Perryville lake in which the delta was built. It is a winding cut in Hamilton shale about 50 feet deep, 100 feet wide at bottom, and ½ mile long. Its general course is northeast. The lowest and longest channel is down in the shale, and forms the east and west valley through which the Lehigh Valley railroad runs. To the east, southwest of Clockville, these channels make steep plunges, but no pronounced ravines have been seen.

On West Stockbridge hill the higher cutting is mostly in great shelves, but lower trenches are in shale, the lowest one, holding the Oneida reservoir, being the largest. The map contours (Oneida sheet) indicate the channeling. The Salina strata are found here at a higher altitude than westward and are reached by the streams at 900 to 1000 feet.

On Eaton hill only the two upper channels are in limestone. The highest has a plunge basin, judging by the map (Oneida

Plate 33

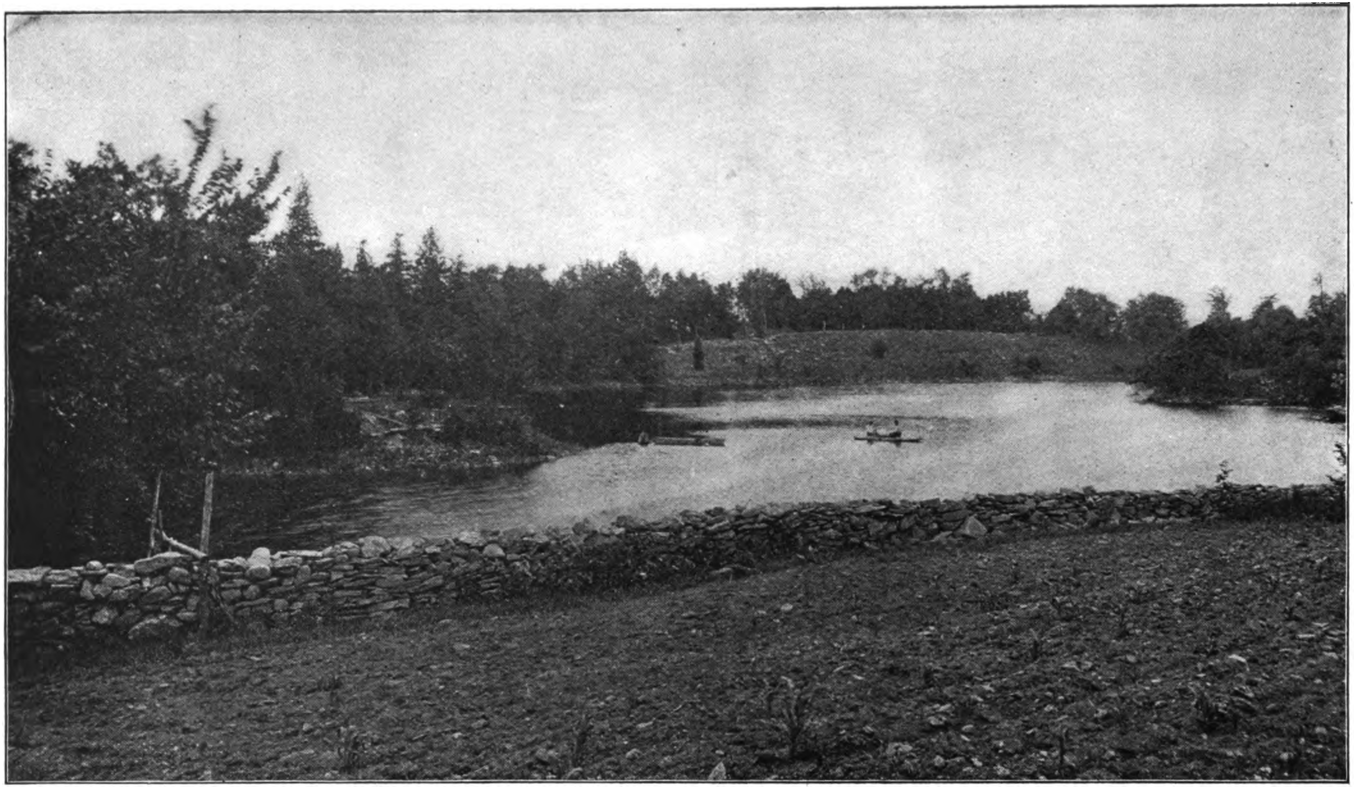


H. L. Fairchild, photo.

ANCIENT CATARACT BASIN: BLUE LAKE

1½ miles e. n. e. of Jamesville; head of High Bridge canyon. Looking southeast, toward cataract. (Compare pl. 25, 31)

Plate 34 To face p. r124

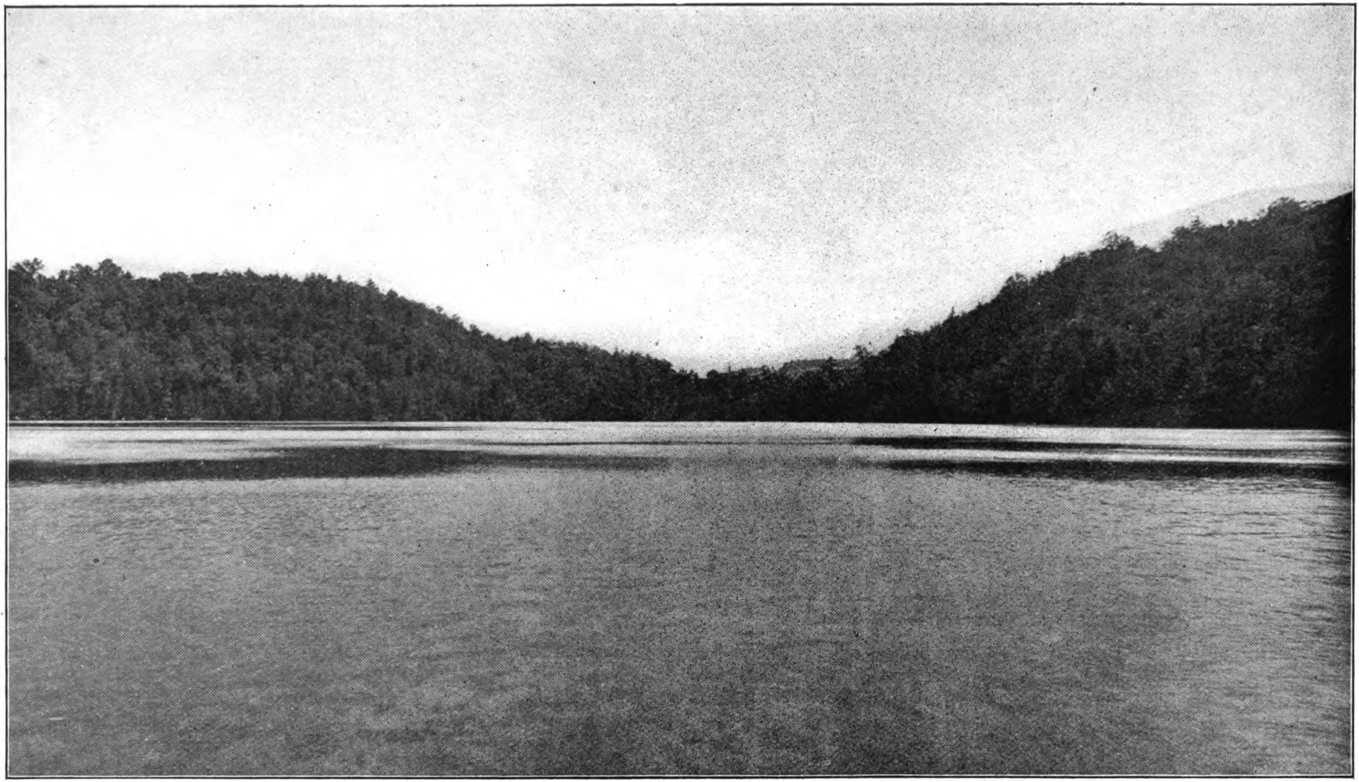


H. L. Fairchild, photo.

EVERGREEN LAKE

2 miles south of Fayetteville. Looking east over the south branch. Basin produced by stream plunge

Plate 35



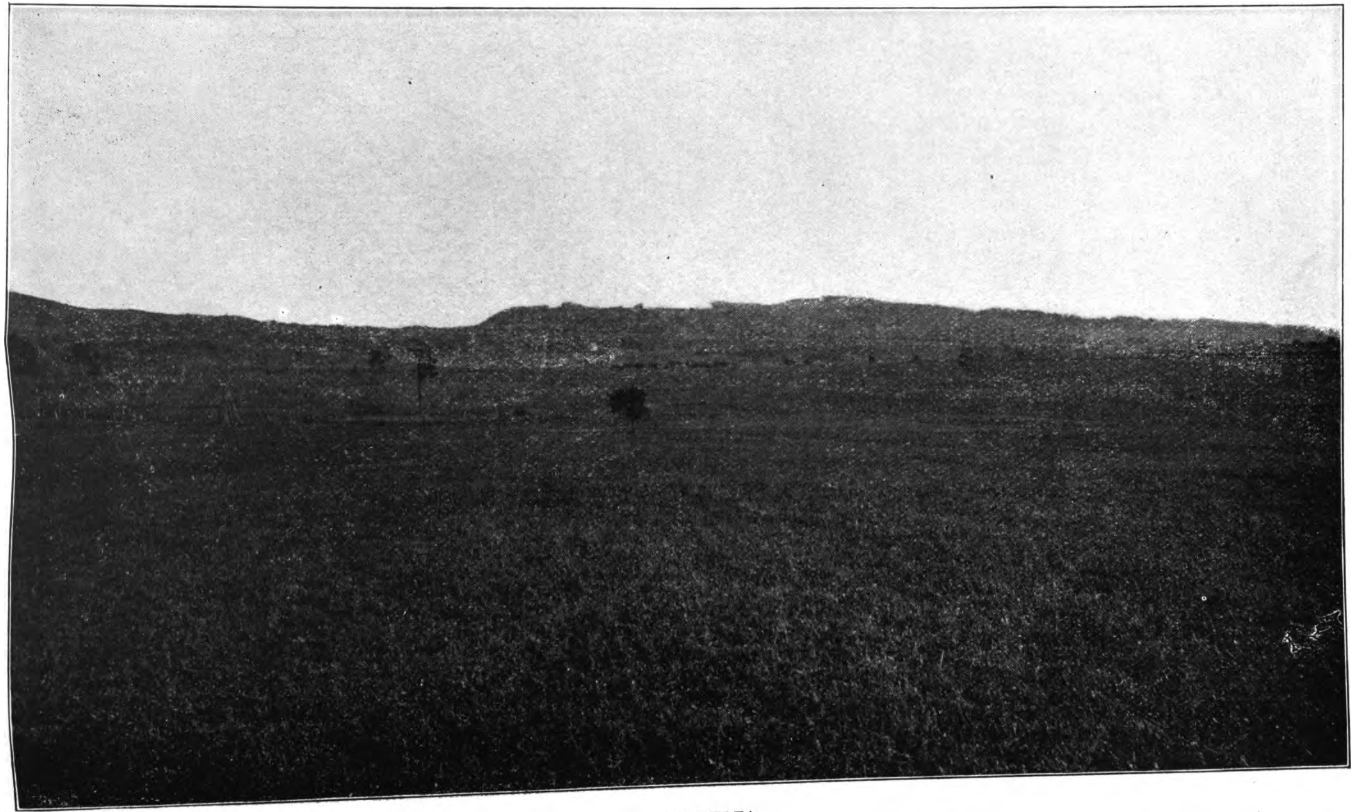
H. L. Fairchild, photo.

ROUND LAKE

2½ miles northeast of Fayetteville. Looking north toward outlet. Basin produced by stream plunge in shales

Plate 36

To face p. r125



H. L. Fairchild, photo.

ANCIENT DELTA

North side of Eaton hill. View looking s. 20° e.

sheet) with a small ravine running southeast down the east slope. The next channel ended on the northeast slope in two short gorges side by side. The lower channels are in shale. The contouring is fairly indicative of the channels.

Deltas

Considering the large amount of excavating done by the swift, plunging streams, the delta deposits are few, practically none for the higher channels. The reasons which occur to the writer for this lack of delta deposits with the higher channels are, 1) the absence of quartzose rocks to furnish undecomposable material, 2) the soluble or decomposable character of the involved strata (shales and limestone) and 3) the steep, high slopes preventing local accumulation. The debris was carried down to fill the valleys, where it was worked over by the present streams, and has been widely spread along the border of the lowland north of the ridges. This material came largely within the reach of the waters of Lake Iroquois, and now constitutes the leveled filling of the plain between Syracuse and Oneida, traversed by the lines of railway.

The most notable delta associated with the higher channels is the one above mentioned at Perryville, ¼ mile southwest of the village, at about 1200 feet altitude by the map (*see* p. 124). It is not a large delta but conspicuous, seen from the north, and is significant as marking a local water level, and thus helping to unravel the history of the glacial waters. A broad delta lies at the north foot of Eaton hill, with a hight of 900 to 920 feet, by the map (pl. 36).

The largest delta seen by the writer in the district lies south of Oneida village, beginning about 1 mile south of the village and stretching southeast for 2 miles toward Kenwood (Oneida community). The remnants of the delta cover perhaps 2 square miles. The New York, Ontario and Western railroad runs along the northeast foot of the delta all the way from Oneida Castle to Kenwood. The summit of the eroded plateau, as given by the map, is 640 feet. This delta is the accumulated debris from the three lower channels of the group on the north slope of West Stockbridge hill, all of which are in Salina shale. Being composed of shale debris, the delta has weathered into erosion forms, and from the north looks like a moraine, but seen from the proper hight, specially from the south, its plateau character is conspicuous (pl. 37).

At High Bridge, south of Fayetteville, is a broad delta remnant of coarse gravel, with map altitude of 600 feet. This is a portion of the deposit left by the river that excavated the White lake gorge.

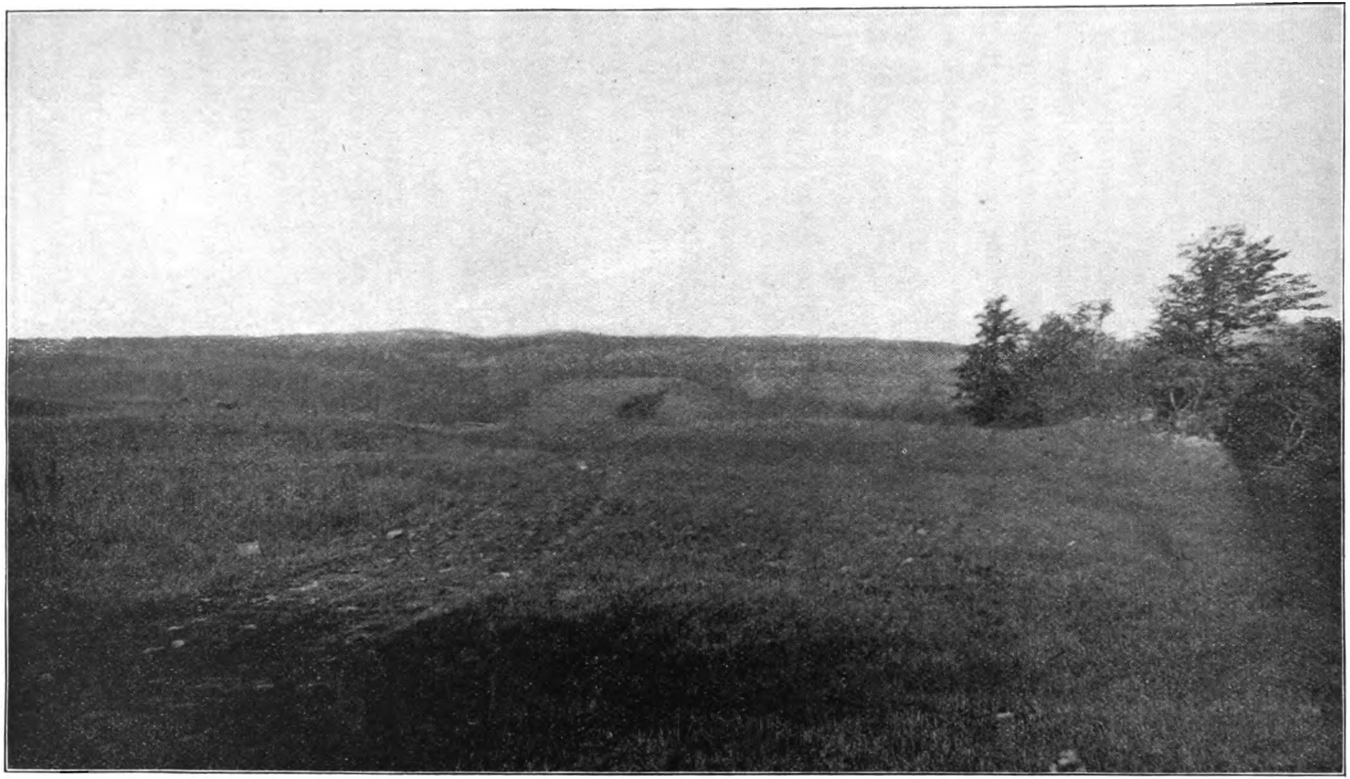
Cataract lakes

Origin. The peculiar lakes in the region southeast of Syracuse have been a subject of comment and speculation for over half a century. These lakes are notable for their location, being in amphitheaters with very steep or even vertical walls of limestone; for their considerable depth as compared with their area; and for the clearness and color of the water, which has caused multiplication of the name, Green lake. Many more or less reasonable and unreasonable explanations of the origin of these lakes have been given: that the basins were of volcanic origin or craters; that they were produced by sinking of the strata, due perhaps to solution of the limestone or of the underlying salt beds; and that they were the result of surface solution of the rocks.

The true explanation of the genesis of these lakes is now perfectly clear. They occupy cataract or plunge basins, similar to that which would exist at the foot of Niagara falls if the Niagara river were to be withdrawn. Indeed, the cataracts which excavated the Syracuse basins were actually the predecessors of Niagara, as they were produced by the falling of the waters of the Erie-Huron basin from the Erian level down to the Ontarian (at that time the Iroquois) level. The lakes all lie in the heads of channels cut by the sub-Warren waters.

No lakes have been found in the plunge basins of the higher channels, though the dry basins exist, probably because they have limestone foundations. The basins holding lakes seem to be either

Plate 37



H. L. Fairchild, photo.

REMNANT OF ANCIENT DELTA

2½ miles southeast of Oneida. Looking northeast

on Salina shale or near enough to the shale to have impervious bottoms. As no description of these has been published, giving a true account of their origin, a brief description will be included here. The lakes are located on the adjoining corners of the Syracuse, Tully and Chittenango sheets.

Jamesville lake. This lake is situated over a mile west of Jamesville, in a cataract basin 160 feet deep to the water and about 400 feet across. The depth of the lake is given as 60 feet. Pl. 31, 32 are two photographs of the lake and basin. The lake was formerly called Green lake, but was recently renamed Jamesville lake by Prof. E. C. Quereau.[1] The altitude of the lake surface is about 600 feet.

Blue lake (pl. 33). This beautiful lake is across the valley from Jamesville, 1¼ miles to the northeast. It is almost a duplicate of the Jamesville lake, but somewhat larger in all dimensions. By eye estimate the basin is over 1000 feet across, the nearly vertical walls being nearly 200 feet high. The lake is some 500 to 600 feet in diameter, with the depth unknown. The map elevation is about 580 feet. The gorge in which this lake lies opens directly north ½ mile into the White lake gorge. The lake has underground outlet through a barrier ridge of coarse material which rises some 10 or 15 feet above the lake. This lake was also locally called Green lake, but it is proposed by the writer to name it Blue lake, which is equally appropriate, and will prevent duplication of names, since the name Green lake is held for another lake of the vicinity (*see* p. 128).

White lake. At the junction of the Blue lake gorge with the gorge leading east to High Bridge is a lake locally called White lake. It is larger than those already mentioned, and is said to be shallow with low shores. Its location at the junction of the two gorges suggests that its genesis is the same as of the other lakes. The map elevation is between 540 and 560 feet.

Evergreen lake (pl. 34). This lake lies ¾ mile south of High Bridge, and close to the west side of the road. It is of irregular

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[1] Topography and history of Jamesville lake, N. Y. Geol. soc. Am. Bul. 9:173.

U shape, inclosing a peninsula that is nearly an island. It is said to be mostly shallow, and the deepest place 50 feet. At first sight its genesis is not evident. The walls are stony rubbish, and no rock was seen in place. It might not unreasonably be regarded as a solution sink, or as a morainal kettle. ¼ mile south occurs a dry basin, also shown on the Syracuse sheet, which lies evidently in the course of a plunging stream. This directs attention to the fact that all the east-facing slope of the hill has been scarred and gouged by immense floods of water pouring over the cliffs. All the features of this slope are either the work of the plunging waters or of some subsequent action, since the floods must have obliterated all earlier features. If these basins were produced by solution of underlying salt beds or other strata and sinking of the surface, the walls should be of rock, and their form should be quite different. No other suggestion of their origin is presented. It seems to the writer that Evergreen lake certainly has the same origin as the other cataract lakes. Its elevation is under 620 feet by the map.

Round and Green lakes (pl. 35). These two lakes, which may be considered together, lie 3 miles northeast of Fayetteville, and close to the Erie canal, south of Kirkville. Their origin is not so certain as that of the lakes above described, but the writer is confident that it is the same. The two lakes, with their surrounding topography, are shown on the Chittenango sheet. They lie near together, at nearly the same level, being separated by a swamp. The elevation of the lower, or Green lake, is given by the map as 418 feet. Their waters are very sulfurous, and the low shores are largely a calcareous deposit. The lakes may originally have been one, and divided by the accumulation of vegetal and calcareous matter over a shallow place. The depth of both lakes is stated by J. H. T. E. Burr of Cazenovia, who has made several careful soundings of each lake, to be 165 feet.

The rocks in which these lakes lie is soft Salina shale, which may account for the sloping walls of the basins, and the absence of a steep or cataract head above the upper lake. Leading to the lakes from the southwest is a fine river channel excavated in the harder shale, which heads in a smooth, swampy col 1 mile northeast of Fayetteville. The flat bottom of the channel is from 20 to 30 rods wide, the breadth on an upper or flood plain level, a few feet higher, is some 40 rods. Nearing Round lake, the channel bottom becomes V shaped, and falls about 120 feet to the lake level.

These lakes certainly lie in the course of an ancient river channel. The argument for their origin is the same as that applied above to the case of the Evergreen lake. If the stream did not produce them, then it could have been only some subsequent agency. Solution and subsidence afford the readiest suggestion. A serious fact against this last suggestion is that the depth of the lakes is too great to be caused by solution of all the thickness of salt ever held in the underlying strata. We must regard the basins of Round and Green lakes as a type of cataract basin in soft shale, while those of Jamesville and Blue lakes represent the type in limestone.

The ice front

Position and form. As the stream channels cutting across the north ends of the ridges were held there by the frontal edge of the glacier, the attitude, form and relationship of the channels give us some knowledge of the position of the ice front at the time the channels were cut, and of its order of recession.

The well known habit of the glacier to follow the valleys or to push farther up the low ground is shown by the curving form of the channels. The higher channels on Eagle, West Stockbridge and Eaton hills show a decided curvature around the ends of the ridges (pl. 16). As these channels either laved the glacier front or were very close to it, the fact is evident that the ice had reentrant angles at the ridges with projecting lobes in the valleys.

Order of recession. The channels were certainly cut by east-flowing waters. It is evident, therefore, that the receiving water at the east of any particular channel must have been lower than the mouth of the effective channel. The falling of the dammed waters was consequently from the east toward the west. This means that the ice front receded or backed away from the escarpment earlier on the east and successively westward; in other words, the ice front inclined to the escarpment, with an open angle toward the east. This agrees also with the known movement or flow of the ice body from the northwest in its last stages in this region, the front of the glacier being at right angles to the direction of flow.

Relative age of the channels

The eastern channels are older than the western, and probably in regular succession westward. It does not follow however that all the channels of a group, both higher and lower, were cut before even the highest of the next group on the west. Such may have been the case with the Eaton hill channels, as they lie south of the parallel of the next westward group, on West Stockbridge hill. The latter group and the Cranson hill group were probably cut more nearly together, since they all trend north of east, and the Cranson hill channels show relatively less effect of plunging. The latter two groups were largely completed before the Eagle hill group, as these latter have gorges and cateracts which indicate low water on the east. A similar statement applies to the groups of large channels southeast of Syracuse, or west and east of Jamesville, for they belong to the sub-Warren drainage of later time, though they lie farther south than the Eagle hill group.

3 CATTARAUGUS–CHAUTAUQUA DISTRICT

Field of special study

The work in this large district during the summer of 1900 was largely in the nature of a careful reconnaissance, but some of the results of the study are sufficiently complete to allow present publication.[1]

The particular field of study was a belt along the divide between the waters flowing to the Ohio river and those flowing to Lake

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[1] In the study of this region the writer was generously assisted by his friend and college mate, B. W. Law, who has his summer house at Collins, near Gowanda, and is intelligently interested in the Pleistocene geology of the Cattaraugus district.

Erie, extending from Gowanda, Chautauqua co., southwest to beyond Chautauqua lake, a distance in direct line of about 35 miles. The line of water parting was examined throughout most of its length from Perrysburg, southwest of Gowanda, to a point 3 miles west of Mayville, with special reference to the channels of overflow of the glacial waters. The distance along the windings of this line is about 45 miles.[1]

Divide and stream channels

The stretches of the divide on the lower ground, nearer Lake Erie, are mostly on moraine drift. A southward bend of the divide around the head of Canadaway creek lies on high ground, having only a thin veneer of ground moraine drift.

Few stream channels cross the divide, and none of great capacity, as the glacial waters in this region escaped southwest past the ice front as soon as the latter had receded some distance from the divide. Only two summit swamps of any considerable size lie on the divide, one of these being at the head of Bear lake, 3½ miles southeast of Brockton, the other at the head of the Little inlet of Chautauqua lake, 2 miles north of Mayville. The location of these swamps with reference to the general topography forbids the idea that they could long have been the outlet channels of large streams, though they carried the local waters of the waning ice front for a time. The map altitude of both of these swamp cols is between 1320 and 1340 feet.

4 miles north of Mayville, at the four corners by the Elm Flat church and schoolhouse, is a short, open, clean-cut channel across the divide, 15 to 20 rods in width. It lies near the head of the Big inlet of Chautauqua lake, with a map altitude of 1340 feet. Another channel occurs in the town of Arkwright, 1¼ miles west of Mud lake. It carried the waters of the small Walnut creek glacial lake over to the west branch of the Conewango creek. The map elevation is 1420 feet.

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[1] The topographic sheets which cover most of the territory involved in this paper are the Silver Creek and Cherry Creek, Dunkirk and Westfield.

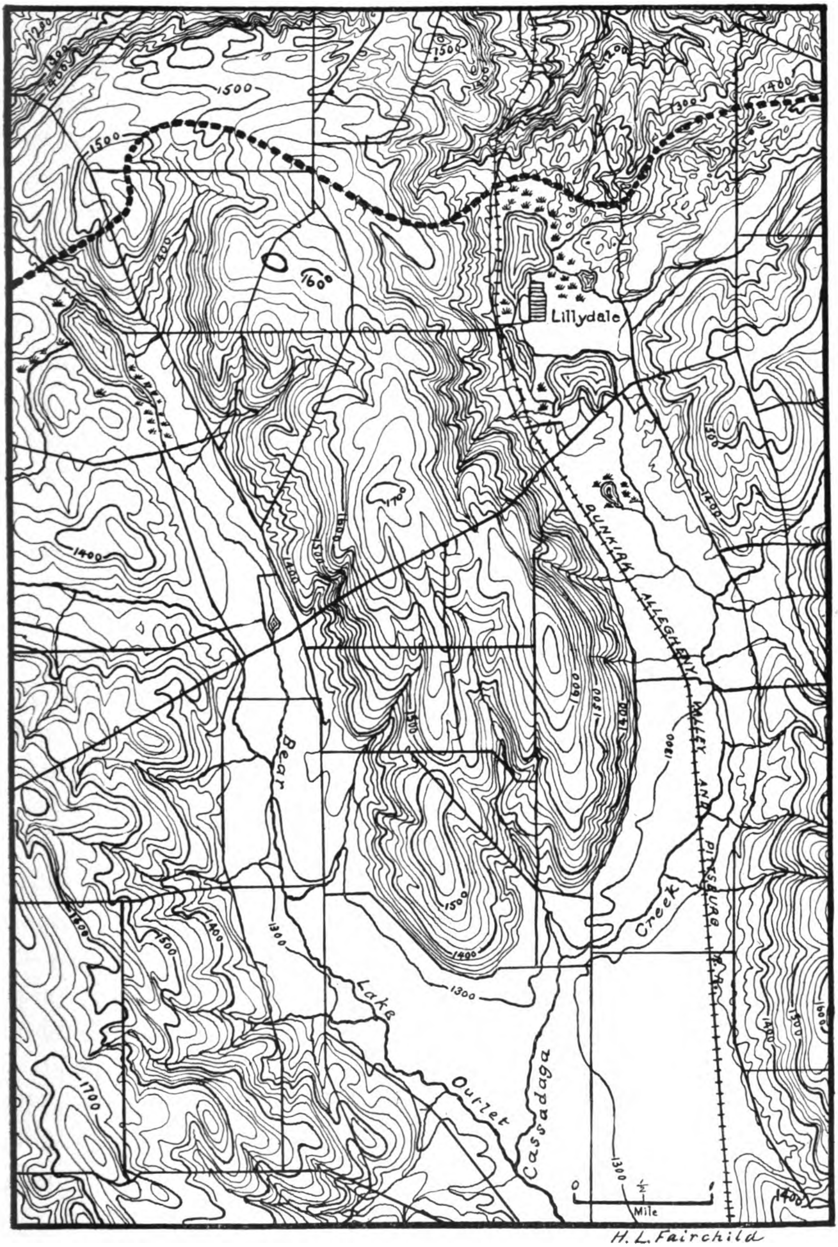
A larger and more important ancient channel was discovered east of the district as limited at the beginning of this writing. It is at Persia flag station on the Erie railroad, between Dayton and Cattaraugus stations, and carried the overflow of the glacial waters held in the Cattaraugus valley over to the east branch of the Conewango. This channel is an important link in the history of the glacial waters of the Cattaraugus valley, but will be described later in the paper (p. 136).

The relationship of the north-sloping land surface to the divide would seem to require considerable flow of water through two others cols, one at East Mud lake, southeast of Forestville, and the other at the Cassadaga lakes, the head of the creek of that name. However, these passes show no definite channels across the water parting, though the south-leading channels certainly carried a heavy flood. This inconsistency will be discussed in the next section.

Channels headed with uncut moraine drift

The two cols just mentioned are good examples of a peculiar topography and relationship of features often found in connection with the valleys leading south from the divide in central-western New York. The accompanying map of the Cassadaga lakes and their surroundings (pl. 38) taken from the Dunkirk sheet, will show the features to be here discussed and will serve as an example of the type. The water parting, here indicated by the heavy, broken line, lies in morainal drift knolls, with only small, indefinite, meandering watercourses among the knolls. Close to the water parting on the south are several shallow lakes, in the head of a broad, well defined valley, which is filled with detrital overwash from the ice sheet. It is certain that the south-leading valley had a flood of water during the long time that the front of the glacier lobe was slowly migrating north up the valley, and that the deep, preglacial valley was a catchment basin for the stream drift, the latter being of great depth. Below the lakes the valley filling has been leveled and smoothed by the stream floods.

Plate 38 **To face p. r132**



H. L. Fairchild

DRIFT-FILLED VALLEYS WITH LAKES AT HEAD

Water-parting shown by heavy broken line. (Copied from Dunkirk sheet)

In cases where the head of the valley is a deep col which is the lowest outlet southward of a capacious north-sloping valley, it is evident that a considerable flow of water must have passed through the col while the ice front was damming the waters in the north valley. The Tully lakes col at the head of the Onondaga valley is a good example of such relationship, and yet it has an uncut moraine divide like the Cassadaga col here mapped. In the case of the Cassadaga col the volume of water ponded north of the divide was not relatively great, but the lake was however of sufficient size to require a distinct outlet channel, which is not found.

Two features of this map of the Cassadaga phenomena do not harmonize with the theoretic requirement. One is the absence of a well defined channel across the divide, and the other is the presence of lakes or depressions in the head of the valley. The latter inconsistency is not difficult of explanation. The valley was filled with the drift, by the glacier and the stream, from the south toward the north, or up stream, following the retreating ice front. The lower stretches of the valley were uncovered by the glacier and filled with the drift sooner than the upper sections. At the head of the valley the supply of drift or filling material gave out rather suddenly as the glacier front passed to the north of the divide, as a lake was then formed which became the catchment basin for the glacial debris. Thus the head of the valley did not receive so much drift as the lower sections, but it would reasonably seem as if it should have received sufficient to fill such shallow basins. And now the question arises, what agency produced such basins in the path of stream action? They evidently are not moraine depressions or kettles, as they do not lie in moraine drift, but do lie in stream-spread deposits. The explanation of these lake basins is that they are ice-block kettles, or areas occupied at the time of the stream work by blocks of glacier ice. When the glacier front receded over the divide, masses of ice became detached from the body of the ice lobe and became surrounded or even buried by the stream deposits. With the ultimate melting of the buried ice, the basins were produced.

To one not familiar with glacial phenomena the above explanation may seem imaginary and farfetched, but it is undoubtedly the true one. Such depressions, either dry or containing lakes, are not rare in the upper stretches of valley plains that have been occupied by glaciers. In the district of our present study the reader can see by the maps that several of the valleys leading south from the divide have small lakes, but only near their heads. Such lakes, in order from east to west, are East Mud lake, Mud lake, Cassadaga lakes and Bear lake. Probably many small lakes and lakelets which once existed have been obliterated by vegetal growth or other filling.

The more common occurrence of detached ice-blocks immediately south of the divides was due to the loss of motion in the edge of the ice sheet which overhung or projected beyond the crest of the divide. In other words, as the direction of ice movement was changed on the angle of the divide from a down-slope to an up-slope, the portion of the glacier on the down-slope was left stagnant, and at the mercy of the stream action.

The other inconsistency, the absence of waterways across the divide, is not so readily explained. The fact of a flow of water across the divide must be assumed, whatever the explanation of the phenomena. We need not mention all the suggestions which might be made, but which a little thought or investigation would show improbable or impossible. For some cases the explanation may possibly be that the divide has been shifted to the north since glacial time. That by the northward differential uplifting some point which in glacial time was lake bottom, and north of the divide, has been lifted so as to become the present divide, and that the water parting of glacial time was at some point which is now down stream and under alluvium in the south-leading valley. The Dunkirk sheet will show the reader that from the upper Cassadaga lake down the valley 7 miles there is a fall of only 6 feet, according to the map. The deformation of the region, as shown by the ancient beaches in the Erie basin, is between 1 and 2 feet to the mile. This is more than the amount of fall in the Cassadaga valley at the present time. But this faint slope of the present valley bottom is probably due to the stream deposition, which probably has here far more than counteracted, for the valley slope, the degree of tilting. Moreover, the position of the lakes would seem to fix the place of the water parting as having been originally where it is now. But the possibility of a changed position of the water parting by tilting of the land surface should be considered in other cases.

Another explanation of the lack of channels in the divide drift may be that at the time when some new and lower outlet was opened for the lake, and this outlet ceased to be effective, the wasteweir or intake of the channel was choked with berg ice and frozen drift, through which or over which the overflow passed. This condition would not be so likely to occur in the case of a large lake which would require a long time, many years perhaps, for the old outlet to be wholly abandoned, even after the new one was opened. It would seem as if ice-obstructed channels would be more likely with smaller lakes, like those we are now considering.

Cols which were water channels are found along the divide in central-western New York showing every gradation from broad, open channels, like the Burns channel above Hornellsville, that has every character of river work, to those which look as if even a brook had never flowed across. And of the several features pertaining to the cols all combinations may be found, due to their relative development or absence. In the district of our present study there is a striking succession of these peculiar cols and filled valleys, indeed they are the most conspicuous features on the four topographic sheets. In order from west to east, they are the two inlets of Chautauqua lake, Bear lake outlet, Cassadaga creek, west and north branches of Conewango creek, and Slab City creek.

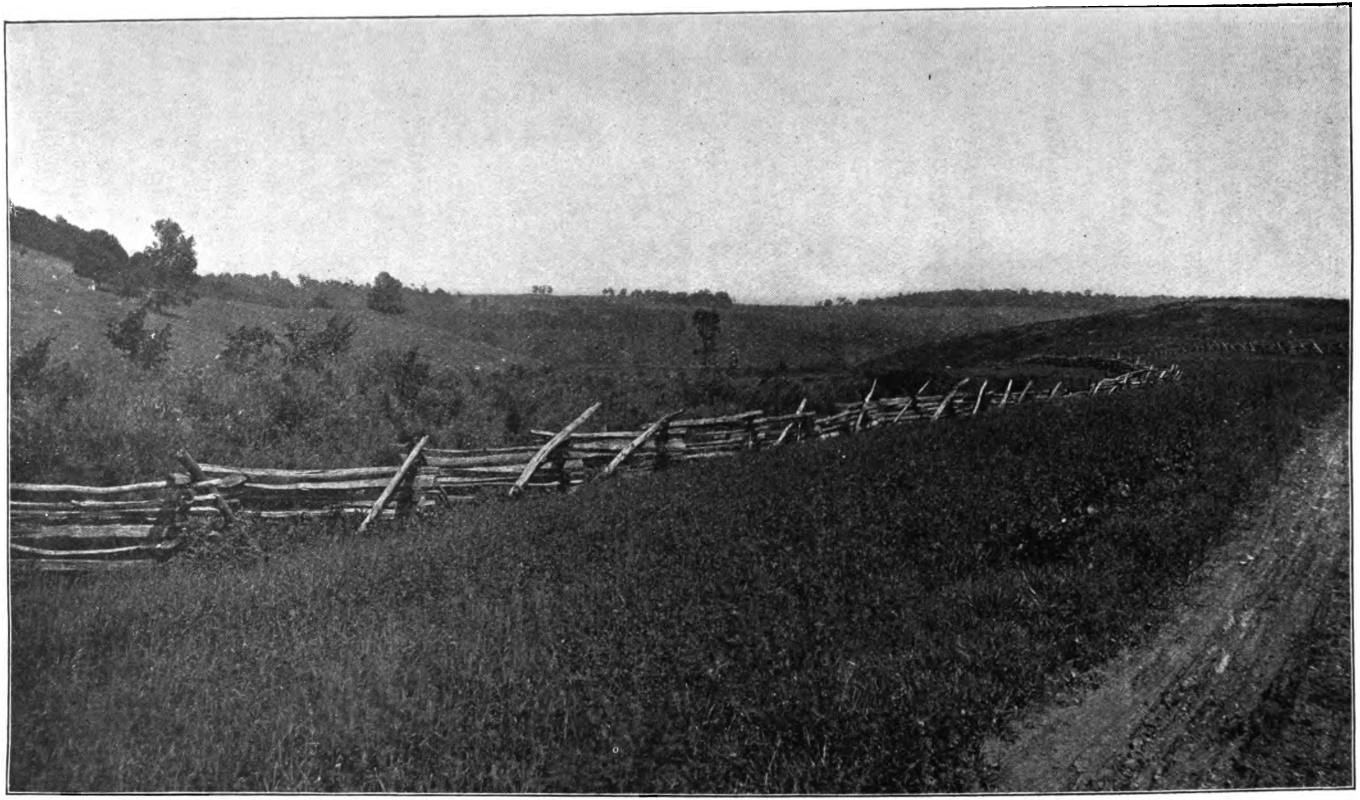
Glacial lakes

Farrington hollow lake. The finest abandoned channel seen by the writer in the district is one that does not lie on the divide, but which occurs at the head of a north-sloping valley far south of the divide. Farrington hollow (*see* the Cherry Creek sheet) is a symmetric valley 500 feet deep, opening north into the valley of the west branch of the Conewango. The location and altitude of the valley are such that it held a glacial lake some 4 miles long, with the outlet at the col about 2½ miles northwest of Cherry Creek village, Chautauqua co. This channel is a clean, open cut across the col with a swamp at the summit; a typical stream channel (pl. 39).

Cattaraugus lake. The only other glacial lake in the district meriting particular attention at this time is that which occupied the irregular basin drained by Cattaraugus creek. Some time has been spent in study of the lake phenomena, but the complete history has not been translated. The main facts can however be presented now. (The topographic sheets are not published, and the reader will be obliged to use some county or state map.)

The main branch of the Cattaraugus rises in Wyoming county and flows westward, being joined above Gowanda by the south branch. The later stages of the ice sheet in this region, spreading from Erie basin, blocked the stream and produced a glacial lake of very irregular shape in the main valley and its tributaries.

The earliest phases of this lake were preceded by smaller local lakes in the tributary creeks from the south, each of which must have had its own outlet across the divide to southern (Alleghany) drainage. Two at least of these primary channels are now used by railroads, one at Machias and another at West Valley. With the farther recession of the ice front toward the northwest, and the blending of the small primitive lakes into one lake, the lowest of the several outlets must have taken the entire overflow. This was probably the Machias channel, with an altitude of 1647 feet, according to the profile of the Buffalo, Rochester and Pittsburg railroad. With still farther retreat of the ice a lower channel was opened farther westward, at Persia flag station on the Erie railroad between Dayton and Cattaraugus stations. The altitude of this outlet is not known with precision, but it is something over 1300 feet.



H. L. Fairchild, photo.

OUTLET OF FARRINGTON HOLLOW GLACIAL LAKE

2½ miles northwest of Cherry Creek village. Looking east (downstream)

The head or intake of this channel is close to the steep bank of the south branch of the Cattaraugus creek. The water parting is a swamp, and the channel bottom is about ¼ mile wide, the railroad crossing it by a low filling. The channel leads northwest a half mile to the railroad, then curves around sharply to the southwest and opens into a valley tributary to the east branch of the Conewango.

Water levels—plateaus and terraces. Sufficient exploration of the upper Cattaraugus valley will probably reveal delta deposits or other evidences of standing water at levels correlating with the Machias and Persia outlets. The writer has so far been able to examine only the water levels in the neighborhood of Gowanda, where they are very conspicuous. These terraces and plateaus will now be described, after which their relations will be considered.

1 The highest plane of water action seen in the region forms a broken plateau southeast of the village, which is conspicuous from some points. The altitude[1] (only a small part of the measurements being by aneroid) is about 1012 feet.

2 Studley plateau is a high level south of the village and above the house of Mr Studley, the latter standing on the next lower level. The altitude is 1032 feet.

3 Broadway level forms a strong terrace south of the village, on which is situated the street of this name. It forms the level stretch on which stand the house of Mr Studley and the gas well derrick. Its altitude is 972 feet.

4 Asylum plateau. This water-leveled plateau and delta plain hold the buildings of the state insane asylum, west of Collins and northwest of Gowanda. The very tall water tank, which is conspicuous for miles around, stands on the highest of several minor terraces, the altitude being 883 feet. The north edge of the plateau, at Shoos four corners, is 873 feet. A lower, broad

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[1] Unless otherwise stated, the altitudes were all determined by instrumental leveling, with the assistance of Mr Law, the datum being the elevations of the Buffalo and Southwestern railroad. By this datum Gowanda station is 773 feet, Collins 861, and Lawton 818.

terrace forms the state farm and the plain on which stands Collins village, its altitude varying from 857 to 852 feet. A strong terrace on the valley side south of Gowanda has the same altitude as the upper asylum level, or 883 feet. This we have called the John Brown terrace.

5 Below or northwest of Gowanda lies a vast stretch of gravel plain locally known as the "Four mile level." It is mostly included in the Cattaraugus Indian reservation. It seems to be composed wholly of water-laid drift, the surface slowly declining to the northwest or downstream. Its altitude near the Shoos four corners, at the north end of the asylum plateau, is 822 feet, but this is near the head of the plain. It is confidently believed that this great plain was formed as the delta, probably subaqueous, of the Cattaraugus creek in the waters of a great glacial lake, which has left as the proofs of its existence the heavy beaches lying either side of the Cattaraugus embayment and around the Erie basin, and known as the Belmore beach. The altitude of the Belmore bars in the vicinity of Collins and North Collins is 840 to 845 feet. This great plain of the Four mile level therefore belongs with the widespread phenomena of the supra-Warren waters, the discussion of which will be taken up in a future paper.[1]

The higher terraces around Gowanda, or those above the Four mile level, belong to the falling waters of the Cattaraugus glacial lake. The highest of these water levels, 1210 feet, is at least 100 feet below the level of the Persia outlet, and consequently must correlate with some lower and later outlet. Such escape was probably to the southeast, past the ice front and along the high ground facing northwest. The study of this slope has not been completed, but sufficient has already been seen to give the

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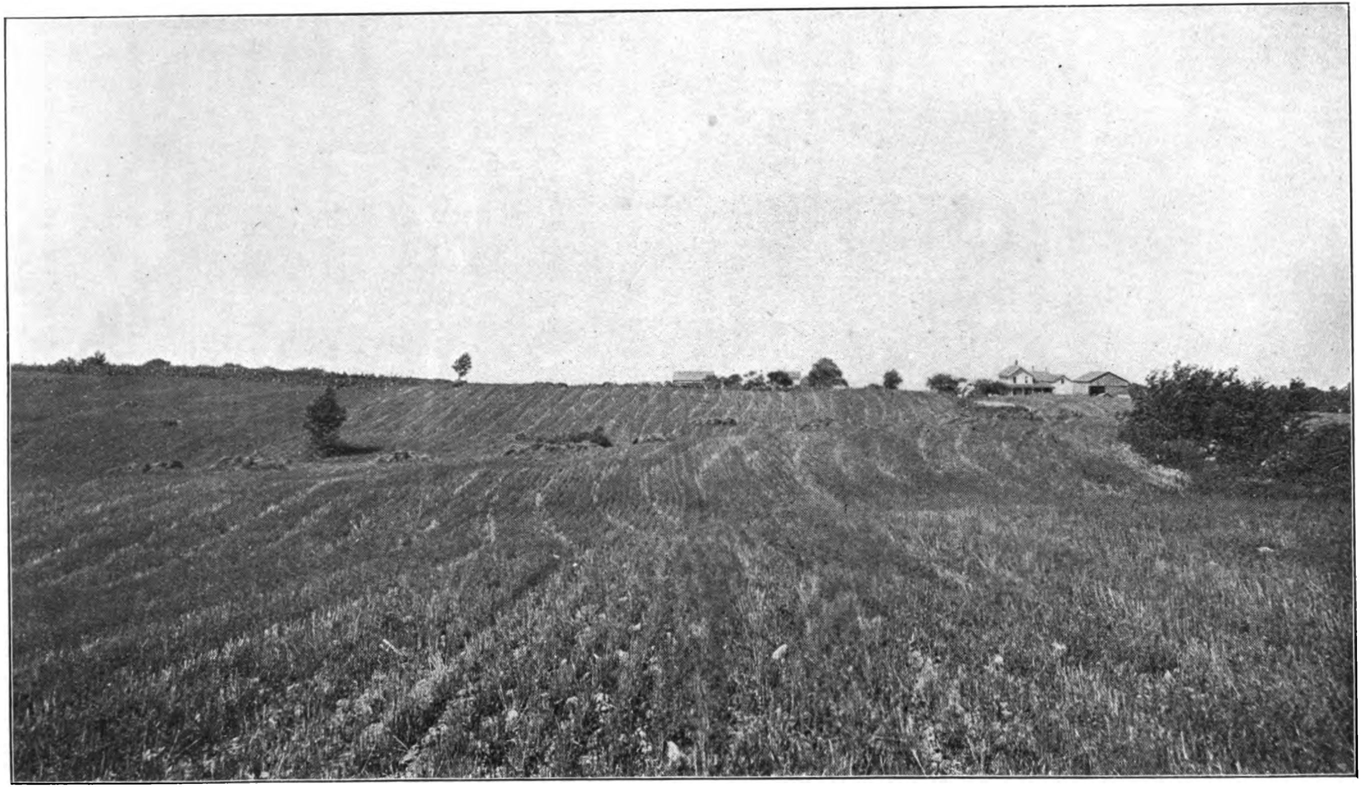
[1] The Belmore and Forest beaches, which lie parallel with the Erie shore, have been partially traced in this district by Frank Leverett, G. K. Gilbert and Frank B. Taylor. They are suggested by the contours on the topographic sheets, the Forest beach being 730 feet at Ripley (Westfield sheet), and 770 feet at Brant (Silver Creek sheet). The Belmore beach is about 70 feet above the Forest, being 800 feet at Ripley and 840 feet in the Cattaraugus embayment.



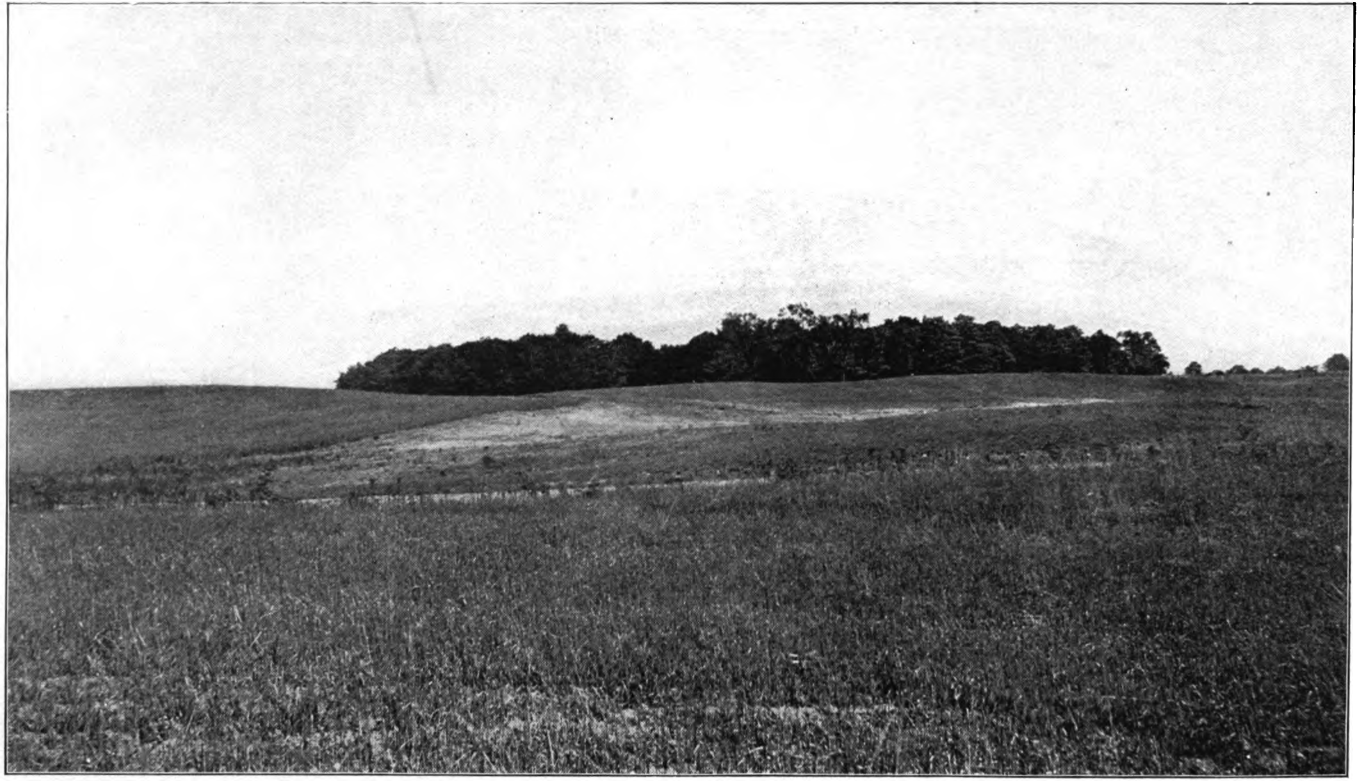
H. L. Fairchild, photo.

GLACIAL DRIFT RIDGES

At 3-corners 4½ miles east of Westfield and 5 miles north of Mayville. View looking west. (Same position as in pl. 41)

Plate 41

To face p. r139



H. L. Fairchild, photo.

GLACIAL DRIFT RIDGES

At 3-corners 4½ miles east of Westfield and 5 miles north of Mayville. View looking north. (Same position as in pl. 40) writer confidence that channels will be found on this slope to correlate with the several levels in the Cattaraugus basin lying in altitude between the Persia and the Belmore levels. Two such channels can be located on the sheets; a rock gorge of considerable dimensions occurs 3 miles south of Fredonia, having a due east and west direction, with a map altitude of 1100 feet for the bottom. Other scourways, with altitude toward 1200 feet, lie east of Fredonia. Northeast of Forestville a pronounced channel terrace is followed by the Erie railroad.

Peculiar forms of morainal drift

Along a stretch of the divide north and northeast of Mayville the glacial drift assumes peculiar forms. For several miles the drift lies mostly in ridges, some of which are so irregular as to be quickly recognized as morainal, but in some areas they are so smooth or drumlinlike that the origin is not apparent. They can not all be drumlins in such cases, as their directions are often in two sets, at right angles to each other.

There is a heavy moraine of typical and strong relief 2 miles west of Bear lake. Westward and southwestward for some 3 miles the drift forms resemble drumlin ridges quite as much as they do moraine. The most peculiar feature is their attitude, being often set at right angles to each other. The photographs which are reproduced in pl. 40 and 41 were taken from the same position, one looking west and one north, near the three corners, about 5 miles due north of Mayville. Decided ridges are crossing the line of vision in each of these views. The morainal character is more suggestive here, however, than in some other places.

The smoothness of this drift can not be due to water action, like moraines deposited under water, as this lies on a high portion of the divide. It may be that the two sets of ridges were made by the same ice edge in recession, one set being the subglacial drift rubbed into drumlin form, while the other set, at right angles, is the true terminal moraine accumulation.

THE QUARRY INDUSTRY IN SOUTHEASTERN NEW YORK

BY

EDWIN C. ECKEL C.E.

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THE QUARRY INDUSTRY IN SOUTHEASTERN NEW YORK

The following paper is purely preliminary in its nature, a more complete discussion of the subject being reserved for a forthcoming museum bulletin on the *Granites and marbles of New York state*, which is to form one of a series on the building stones of the state. The area discussed in the present paper includes the counties of New York, Queens, Westchester, Putnam, Dutchess, Rockland and Orange. A few quarries in the western half of Fairfield county, Ct., are also described.

The data here presented have been collected during the past four years field work in the area under consideration. Descriptions of several of the quarries have been furnished the writer by Mr H. C. Magnus, who spent some time in 1900 on field work for the state museum in central Westchester county, and by Mr B. F. Hill, who was engaged for several field seasons on work in Putnam county. The writer is also indebted to Mr Joseph Morje for valuable assistance in the preparation of the material for publication. Other acknowledgments are made in the course of the paper.

GEOLOGY OF THE AREA

The area discussed in the present paper, though relatively small, contains representatives of all the geologic systems from the pre-Cambrian to the Trias which occur in New York state. The geologic discussion here presented is merely a summary of those facts of importance in connection with the quarry industry of the area. The areal distribution of the various formations is very complicated and can hardly be explained without reference to a geologic map of fairly large scale. The new edition of the geologic map of New York, on a scale of 5 miles to the inch, will be found serviceable in this connection. Westchester and New York counties, with small parts of Rockland, Orange and Putnam, are well shown on the geologic map of a part of southeastern New York by Dr F. J. H. Merrill, published in 1895.

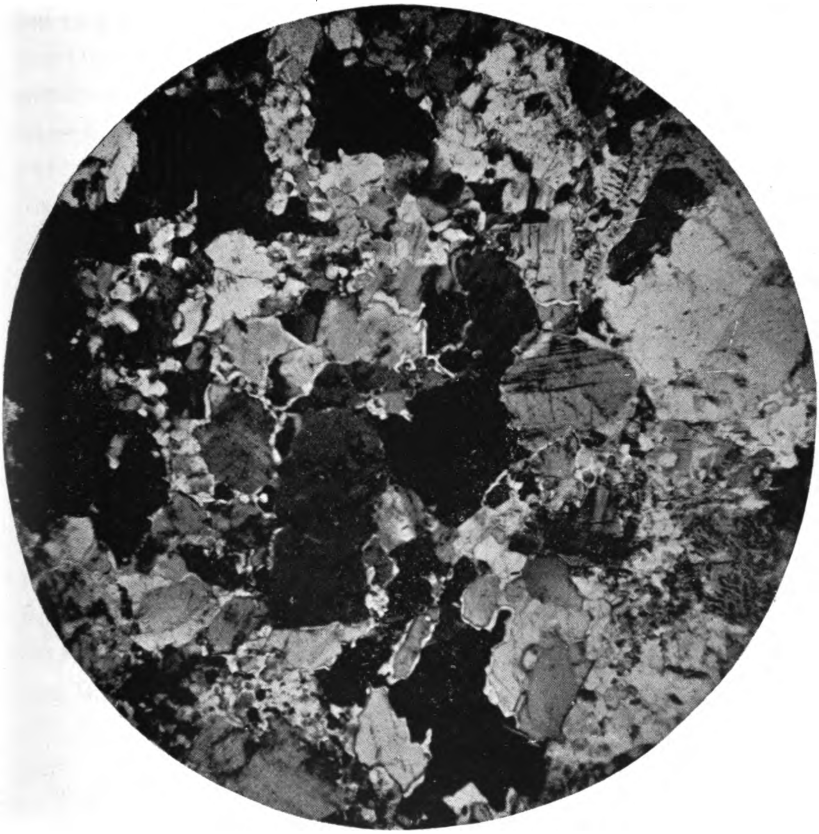
For a detailed discussion of the geology of this part of the area, reference must be made to Dr Merrill's paper on the "Crystalline rocks of southeastern New York," published in the 50th annual report of the New York state museum. Reports on Orange and Rockland counties, by Dr Ries and Dr Kümmel respectively, have also been issued. The Devonian outlier extending in Orange county from near Cornwall to Greenwood lake, has been discussed in detail by Mr N. H. Darton.

The oldest formation in the area is a series of gneisses of pre-Cambrian age, forming the mass of the Highlands. To the northwest of this range is the great lowland, based on Cambro-Ordovician limestones and shales. A structural basin lying on the northwest flank of the main body of pre-Cambrian rocks, but separated from the Paleozoic lowland in Orange county by a series of small pre-Cambrian outliers, contains Upper Silurian and Devonian formations. East and southeast of the pre-Cambrian mass, on the western side of the Hudson, is a region in which the sedimentary rocks have been highly metamorphosed, the sandstones, limestones and shales of the normal Cambro-Ordovician appearing here as quartzites, highly crystalline limestones, and schists. As a further result of the forces to which they have been subjected the strata, originally laid down in a nearly horizontal position, now form a series of folds, trending generally northeast and southwest, both Paleozoic and pre-Cambrian beds being involved in these folds. South of the pre-Cambrian, to the west of the Hudson river, these altered Paleozoic rocks are almost entirely overlain by the Newark rocks, which cover most of Rockland county. In addition to the formations noted above, which are parts of a normal succession, igneous rocks occur as intrusives of later date.

SUCCESSION OF THE FORMATIONS

Pre-Cambrian rocks

The pre-Cambrian rocks of southeastern New York consist of a series of gneissoid granites and gneisses, locally schistose. In Westchester county the more massive (and in general more



F. J. H. Merrill, photo.

Pre-Cambrian gneiss, Lake Mahopac N. Y.
Photomicrograph in polarized light, enlargement 22 diameters.

basic) lower gneisses are overlain by a highly foliated gneiss, described by Dr F. J. H. Merrill as the Fordham gneiss. This is a well banded bluish to gray gneiss, consisting of alternating layers of quartz, orthoclase (or microcline) and mica (usually biotite).

Lithologic differences, fairly constant over large areas, have led to a tentative fourfold division of the pre-Fordham gneisses; but the grouping depends on composition rather than on superposition, and has therefore no chronologic significance. The names for these subdivisions have been used, in manuscript only, by the present writer: and the subdivisions will not be discussed in the present connection.

Various authors have included in the pre-Cambrian both the large area of white limestone of Sussex county, N. J. and Orange county, N. Y. and smaller isolated areas which occur in the Highlands of Putnam and Orange counties. Recent field work by the writer in these smaller areas seems to disprove this conclusion, at least so far as some areas are concerned; and it is probable that the entire question may still be considered open. In the present paper, however, these Highland limestones have been discussed separately from the undoubtedly Paleozoic limestones and marbles. Lithologically, these white limestones differ but slightly if at all from the more highly crystalline portions of the Stockbridge, and like the Stockbridge and Barnegat are usually highly magnesian.

Poughquag quartzite

In Dutchess, Orange, Putnam and Westchester counties a relatively thin quartzite usually underlies the Cambro-Silurian limestones. In Stissing mountain and at other points this quartzite has been found to contain Lower Cambrian (Georgian) fossils. It is essentially continuous, stratigraphically, throughout the counties above named, few contacts of the Stockbridge limestone with the pre-Cambrian gneisses failing to show this intervening quartzite. In its lithologic character it is very uniform. Dr Merrill described it in 1896 as the Lowerre quartzite, while the formation names Vermont and Cheshire have been given it by the New England geologists. The name recently adopted for it is Poughquag quartzite (Dana 1872) in recognition of the fact that its thickness, lithologic character and stratigraphic position are well shown at Poughquag, Dutchess co. N. Y. A typical exposure of the Poughquag quartzite occurs on the south side of Peekskill creek near its junction with the Hudson river. This is well shown on pl. 54, the slaty cleavage of the quartzite being particularly noticeable.

Stockbridge and Barnegat limestones

The Barnegat or blue limestone of Orange and southwestern Dutchess county and the crystalline Stockbridge limestone of the other southeastern counties and western New England, are more or less highly metamorphosed equivalents of the Cambro-Silurian limestones of northern Dutchess county. As a whole, the Barnegat and Stockbridge formations are predominantly magnesian. They rarely carry sufficient magnesia to qualify as true dolomites, however; and contain occasional beds of almost pure lime carbonate.

The crystalline Cambro-Silurian limestone of Westchester county was described as the Inwood limestone by Dr F. J. H. Merrill in the paper previously cited. These Westchester county limestones are essentially continuous, stratigraphically, with the Stockbridge limestone of the Taconic region; and in order to prevent two names being used for the same formation, the formation name Stockbridge has been accepted as that of earlier date.

Mather in 1842 described the semicrystalline blue limestone of Orange county as the Barnegat limestone. Though there seems to be little doubt of the essential equivalence of the Barnegat and Stockbridge, it seems best to retain both names as the Stockbridge probably includes Trenton beds, which in the less metamorphosed area of Orange county and New Jersey can be differentiated from the Barnegat. South of the New York line the names Kittatinny and Wallkill have been applied to the Barnegat limestone, but these can hardly be regarded as tenable in view of the many other names of earlier date.

Hudson shales and schists

The Hudson shales of the Hudson valley are represented in the metamorphic area of southeastern New York and western New England by a thick series of slates and mica schists. The transition from shale through slate to schist can be well observed in traveling across Dutchess county from west to east in the latitude of Poughkeepsie; and the term Hudson schist has recently been adopted in place of the terms Manhattan schist (of New York geologists) and Berkshire schist (employed by the United States geological survey workers in New England). The Hudson formation is of little economic importance, though much schist has been employed in foundation and retaining wall work on and near Manhattan island, and thin layers of sandstone occurring in the shales have been worked in Dutchess county.

Green Pond conglomerate

The name Green Pond conglomerate was given by Darton in 1894 to a formation occurring on the borders of the Devonian outlier noted on p. r144. The principal exposures of this formation, in the area here discussed, are west of Cornwall station and in Pine hill near Highland Mills, both in Orange county. The rock is a conglomerate consisting of white to pinkish quartz pebbles, embedded in a reddish silicious matrix. Darton states that in this vicinity the formation is not over 60 feet thick. In stratigraphic position the Green Pond conglomerate, Pine Hill quartzite and Longwood red shales correspond approximately to the Shawangunk grit of Ulster county, and to the Medina (including Oneida) rocks of western New York.

Pine Hill quartzite

The name Pine Hill quartzite is here proposed for a series of quartzite beds overlying the Green Pond conglomerate and underlying the Longwood shales. The formation is well shown in Pine hill, east of Highland Mills, Orange co. Transition beds between the quartzite and conglomerate and between the quartzite and shales occur; but in general the lithologic distinctions between the formations are evident. The Pine Hill formation is 250 feet thick in New Jersey, according to Darton, thinning northeastward to 5 or 6 feet at Cornwall.

Longwood red shales

Darton applied this name in 1894 to the series of shales overlying the quartzite last described. The formation, in Pine hill, shows a thickness of 75-100 feet, and is of considerable (local) economic importance. The shales are in general red, occasional bands of olive shales locally occurring.

Cornwall limestones

A series of thin beds of limestone overlies the Longwood shales at several points in Orange county. These beds carry fossils which serve to correlate them paleontologically with the Lower Helderberg and Waterlime rocks farther west. The term "Cornwall limestones" is not here proposed as a formation name, but is used merely as a convenient designation for the series till further field work shall have decided the extent to which subdivision can be carried. No quarries are at present worked in these limestones.

Newfoundland quartzite

This formation, usually a light colored quartzite but locally conglomeratic, carries at some localities fossils which would correlate it paleontologically with the basal Devonian Oriskany quartzite. The formation name here proposed is in allusion to the exposure of the quartzite at Newfoundland N. J., where its lithologic and paleontologic characters are well shown and were described by Britton and Merrill in 1886.[1] It is exposed at several other points along the margin of the Devonian outlier in both New York and New Jersey. No quarries in this formation are worked in the area under discussion.

Monroe shales

This name was applied by Darton in 1894 to the dark colored shales underlying the Schunemunk conglomerate and in places overlying the Newfoundland quartzite. Fossils correlate them approximately with the Hamilton of the counties farther west. These shales are quarried at several points for local use as road metal, but are of no great economic importance.

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[1] N. J. state geol. Rep't. 1886.

Bellvale flags

The name Bellvale flags was given by Darton, in 1894, to the hard, thin bedded gray sandstones which appear, overlying the Monroe shales, in Schunemunk, Bellvale and Bearfort mountains. Plant remains occur[1] in these flags, and fix their age as middle Devonian.

Schunnemunk conglomerate

Overlying the Bellvale flags in the mountains above named is a conglomerate of quartz and quartzite pebbles in a reddish silicious matrix. In 1894 Darton named this the Schunemunk conglomerate. He states that lithologically it differs from the Green Pond conglomerate in containing quartzite pebbles, which are absent in the latter.

Newark beds

The Newark beds of central and western New Jersey have been divided by Kümmel into three superposed "formations." These "formations" change in lithologic character as the New York line is approached. Two of them, according to Kümmel, appear in Rockland county N. Y. They have not been mapped separately however, and will not be separately treated in this paper. Calcareous conglomerates, which appear near the northern edge of the Newark area, have afforded some lime.

IGNEOUS ROCKS

Cutting certain of the formations above noted, granites and other igneous rocks are frequently found in dikes or masses. These igneous rocks vary greatly in composition and texture as well as in economic importance. Of the many varieties present, four show well marked and distinct types and occupy definite areas of considerable size. For this reason they have been assigned names as follows (being named after the localities at which they are best developed): Yonkers gneiss, Harrison diorite, Cortlandt series (norite, diorite, etc.), Newark diabase. The remaining rocks of igneous origin, occurring in areas too small to be separately named may, for our present purpose, be grouped as granites.

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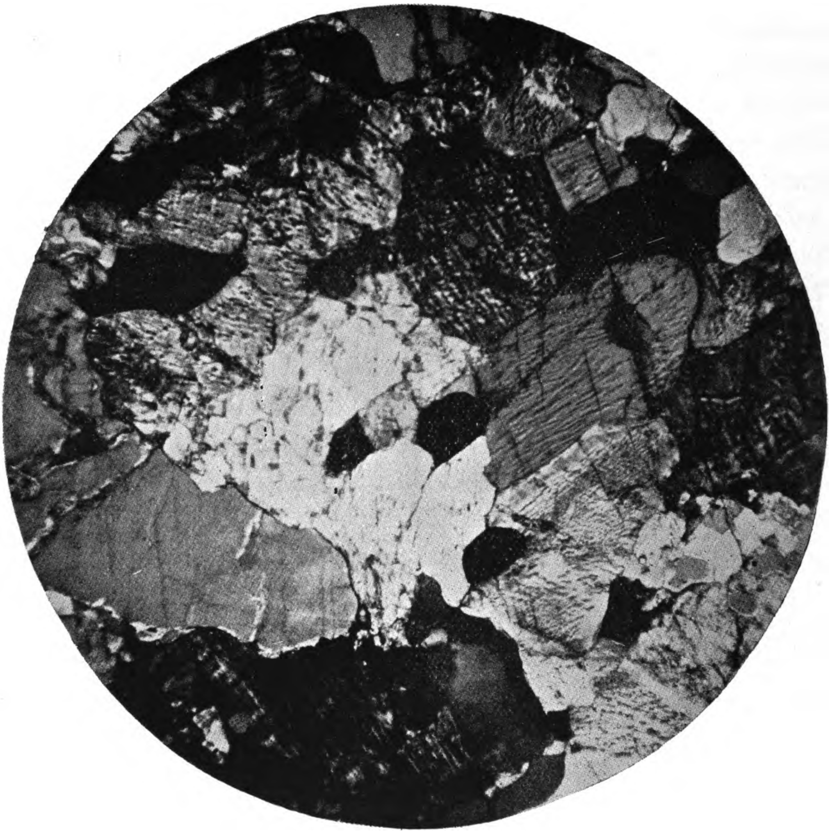
[1] Martin, D. S.
Prosser, C. S. N. Y. acad. sci. Trans. 11:132-51.

QUARRY INDUSTRY OF THE AREA

PREVIOUS PUBLICATIONS

Prof. J. S. Newberry, in his report on *Building and ornamental stones*, Philadelphia exposition, 1876, discussed at some length the Tuckahoe and Pleasantville quarries, and their product. The *10th census report on the stone quarry industry* contains short notes on the marble quarries and a brief mention of the Lefurgy quarry (in Fordham gneiss) at Hastings. In addition, however, this report contains an exceedingly valuable and comprehensive paper by Dr A. A. Julien on "Stone construction in New York city and the vicinity," with detailed information regarding the durability, etc. of all stones, domestic or foreign, used here. In his two reports on the *Building stone of New York state*, published as bulletins 3 and 10 of the New York state museum, Prof. J. C. Smock describes the quarries of the entire state in great detail, giving physical and chemical data in bulletin 10. These reports, abstracts of which have appeared in bulletin 15 of the New York state museum, contain the best descriptions yet published of the quarries and quarry industry in Westchester county, being defective only in regard to the Yonkers gneiss, quarrying in which was not actually begun till several years after the publication of the bulletins. All these reports, however, suffer from one common and unavoidable defect. At the time at which they were written the geologic structure of the area had not been made out with any degree of certainty, and the reports consequently err in grouping together quarries which are worked in entirely different geologic formations. For this reason, it has been in some instances extremely difficult to identify the material on which the tests quoted were actually made.

A report on the geology of Orange county by Dr Heinrich Ries, published in the 15th report of the New York state geologist, contains notes on the quarry industry in Orange county.



F. J. H. Merrill, photo.

Pre-Cambrian gneiss, Breakneck mountain, N. Y.
Photomicrograph in polarized light, enlargement 22 diameters

GRANITE: INCLUDING GNEISS, DIORITE, TRAP, ETC.

Lower pre-Cambrian gneisses

Storm King station, Putnam co. Quarries (1) in Breakneck mountain at this station formerly furnished a large amount of stone for building work and also of crushed stone for railroad ballast. Bailey's quarry, (1) a few hundred yards south of the station, is still worked at intervals, but the output is small. The rock in which the quarries are located is a medium grained gneissoid granite containing a large amount of hornblende. In color it varies from dark greenish to redish. A thin section of this rock is shown on pl. 43.

Carmel, Putnam co. Two quarries in pre-Cambrian gneiss are located one (3) on the west side of the West Branch reservoir, the other (2) on the east side of the reservoir. Both furnished material for the dams and reservoir walls.

Peekskill, Westchester co. A small quarry located near the east bank of the Hudson river, about 3 miles northwest of Peekskill, has not been worked for some years. The rock is a rather coarse grained, light colored, gneissoid granite.

Glenham, Dutchess co. A reddish gneiss has been quarried to a small extent near Glenham, Dutchess co. (4). The product was used for macadam on local roads. The quarry is located north of and near Fishkill creek, in the small outlier of pre-Cambrian gneiss which extends from near Glenham northeastward to Vly mountain. The material is unsuitable for structural work.

Theill, Rockland co. Pre-Cambrian gneiss has been quarried just north of the station of the New Jersey and New York railroad at Theill, Rockland co. (5). The material outcropping at the quarry is closely jointed, and breaks readily along the joint planes. It has been largely used for macadam on neighboring roads, but will probably be superseded by trap from the new quarry south of Theill.

Suffern, Rockland co. Several quarries (6) are worked north and northwest of Suffern by Rice Bros. and the Hillburn granite co. The rock here quarried is a pre-Cambrian gneiss, not very highly foliated, and consisting chiefly of quartz, plagioclase (with subordinate orthoclase) and hornblende. The feldspars are usually white, varying to reddish; and the gneiss is accordingly gray to light reddish in color. Part of the stone is used, rough dressed, for foundation and wall work; but a considerable quantity is cut by Copeland & Son at Suffern, being used chiefly for monuments.

Arden, Orange co. Several quarries (7) between Arden and Tuxedo Park have been worked quite extensively for road metal. The material is a hornblendic pre-Cambrian gneiss, not suitable for dressed stone, but as road metal producers the quarries are of some local importance.

Monroe, Orange co. A pinkish gneiss occurs in an area of considerable size about 2½ miles southeast of Monroe, Orange co. It has never been worked, but judging from the outcrop should furnish stone of good quality. So far as color is concerned, it is probably the handsomest granite in southeastern New York.

Fordham gneiss

The Fordham gneiss is typically a light grayish or bluish, well banded gneiss, consisting of biotite, orthoclase and quartz. Its upper[1] beds near the contact with the Poughquag quartzite are always highly quartzose; and this upper part of the formation is possibly of sedimentary origin. The Fordham gneiss has been largely used for foundation stone and other uncut work. The Hastings quarry formerly sold a fair proportion of its product as cut stone, but of late years little of this grade has been marketed. It has also been used to some extent for macadam, but is hardly well fitted for this purpose as it generally breaks into flat pieces when put through a crusher.

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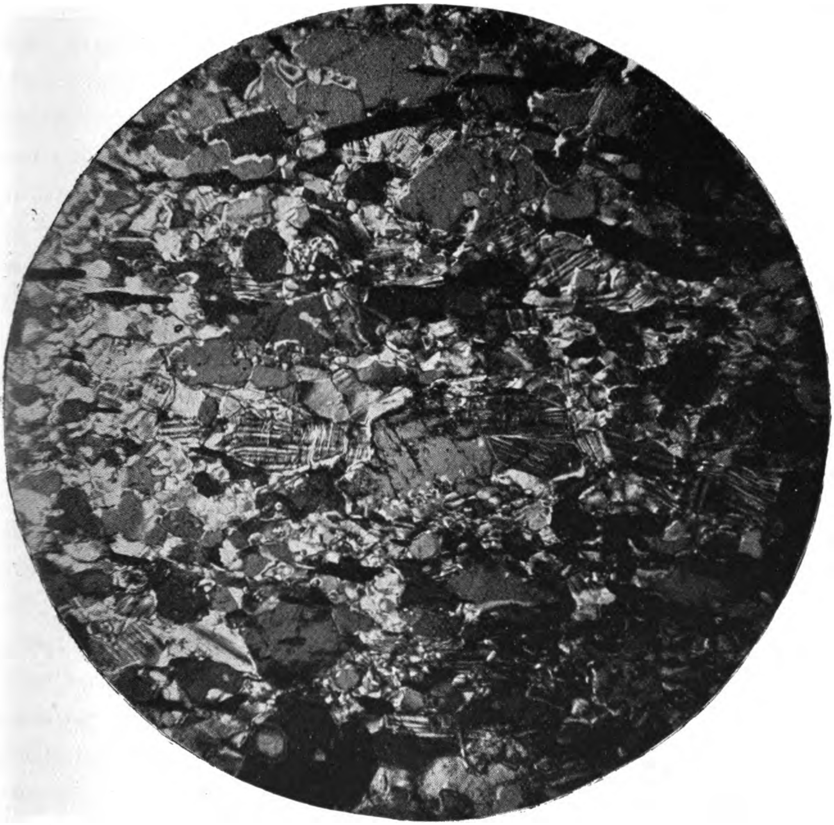
[1] "Upper" is used here in a geologic sense. Folding of the rock series may cause the newer (and geologically "upper") beds to apparently underlie the older (and geologically "lower") beds. This is well shown at the old marble quarry near Hastings, Westchester county. The series here has been sharply folded so that the limestones are shown dipping to the east, apparently under the quartzite and gneiss which are exposed near the top of the eastern wall of the quarry; but the limestone is really newer than the gneiss and quartzite.



F. J. H. Merrill, photo.

Fordham gneiss, Lefurgy's quarry, Hastings N. Y.
Photomicrograph in polarized light, enlargement 22 diameters

It has, however, been used to a considerable extent for railroad ballast.

Hastings, Westchester co. *Lefurgy's quarry* (9). Owned by ——— Lefurgy; operated under lease by William Nichols jr. Known at one time as Munson's quarry. Situated about half a mile west of Mt Hope station, on the western side of the gneiss ridge. It is opened for a distance of about 350 feet along the strike, and is about 100 feet wide. The west wall is 30 feet high at its northern end, running down to near ground level at its southern. The east wall is about 100 feet high at its northern, and 20 feet at its southern end. The floor of the quarry is at present only a few feet below ground level, though it was at one time worked 10 feet or more below, this low cut having been subsequently refilled. The entrance to the quarry is at the south end where a road leads out to the main road to Hastings.

The west wall shows biotite schist and much crumpled gneiss, and has been practically untouched since the opening of the quarry, all the development having taken place toward the east and north. The northern face shows a good quality of light gray or bluish gneiss, typical Fordham, a thin section of which is shown on pl. 45. In it are two seams 2 to 3 feet wide, of hornblende-biotite gneiss, regularly laminated, and of rather good grade. They would certainly furnish attractive cut stone. The east face is now beginning to cut a crumpled area, containing frequent interbeddings of a rock composed of pink feldspar, a silvery mica, and some garnets. For this reason the quarry has probably reached its extreme eastern development, most of the stone now being taken from the north face. The pink intrusive mentioned seems to be usually accompanied by a walling, 2 inches or so thick, of biotite schist. Near it quartz lenses and stringers are common, and are also usually walled by biotite schist. Strike and dip average n. 24° e., 71° e.

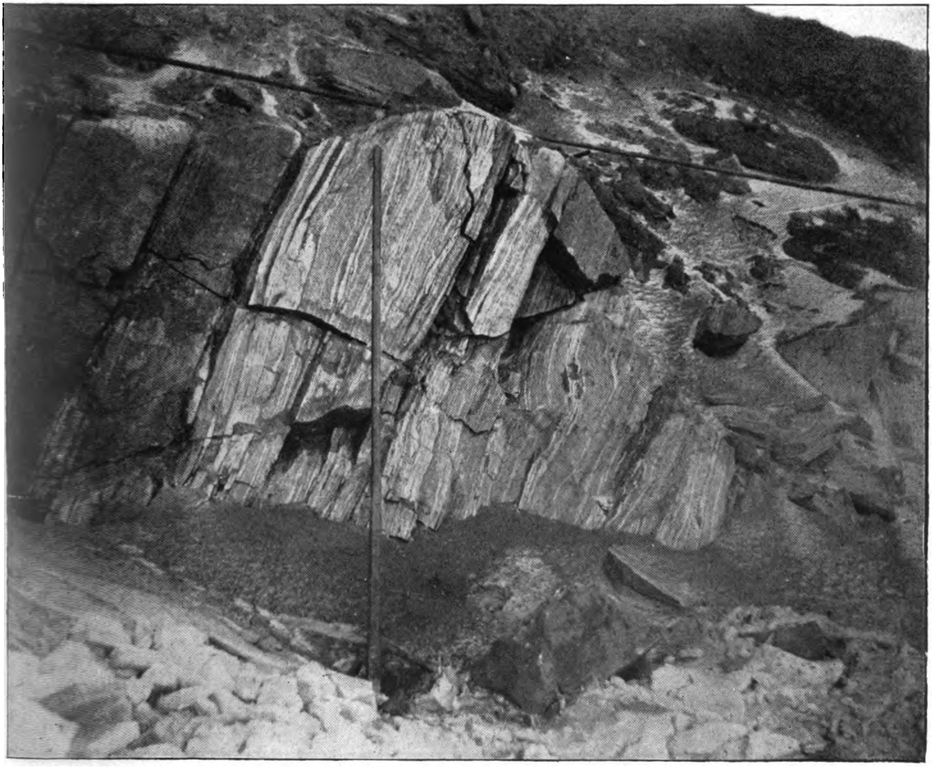
Two derricks (horse) are in place. There is usually little trouble from water, though in certain seams enough has been encountered to embarrass the blasting (black powder).

For the past three years no cut stone has been furnished by this quarry. In 1898 the total output was valued at about $1300, and was mostly used for foundations and backing. For this material $1.50 a cubic yard is obtained. Expense of lifting, handling and transportation prevents competition, even locally with the New England and Hudson river stones. The quarry will probably soon be abandoned because of the poorness of east and west walls, and because adjoining lots have been sold for building. Mr Nichols then expects to commence quarrying on his own land, a little farther north on the same ridge.

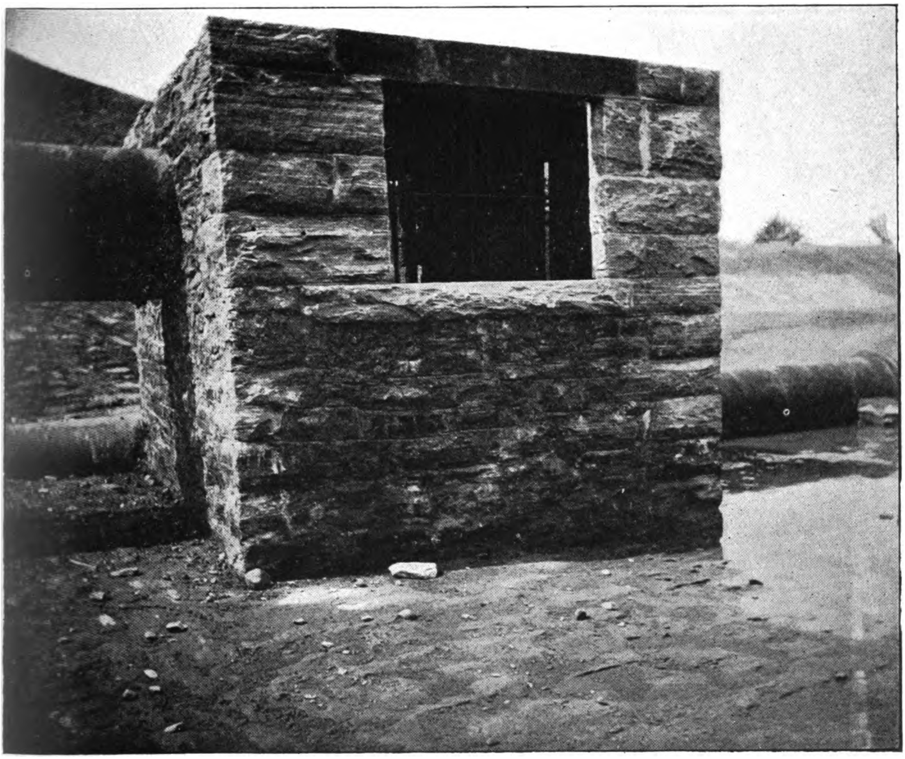
Uniontown, Westchester co. A quarry (10) here was worked for a time in order to get rough stone backing for one of the Warburton avenue bridges. The opening is in a light colored (gray) gneiss, with several pink seams. The mass of the rock, however, shows little or no injection. Strike and dip n. 25° e., 56° e. The product shows too much contortion in the layers to permit the quarry, if ever reopened, to become a serious competitor of Lefurgy's.

Bryn Mawr, Westchester co. Along Palmer avenue, west of Bryn Mawr, near Fort Field reservoir, two small openings (12) have been made in Fordham gneiss. The easternmost is in a rather poor grade Fordham, minutely crumpled and breaking into tabular pieces. The westerly opening is in better rock, and supplied part of the stone for the reservoir walls and gatehouse. Both openings were worked later to supply macadam for Palmer avenue. Pl. 46 shows a face of the Fordham gneiss exposed in excavating for Fort Field reservoir, and pl. 47 the gatehouse, built from good specimens of this gneiss.

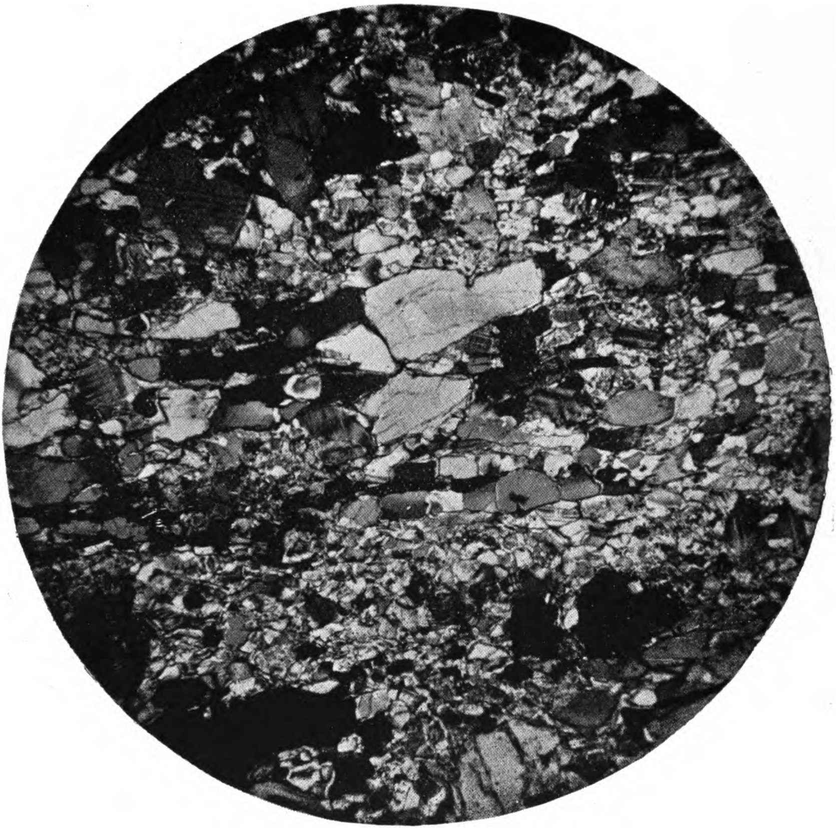
Lowerre, Westchester co. In Lowerre small quarries (11) were opened in 1898. The rock was a rather poor Fordham gneiss, with granite injections along certain bedding planes and a pegmatitic dike crossing the bedding. The total product to May 1, 1899, was about 2000 loads. Rough stone brought 75c to 85c a load, while larger stone, roughly trimmed, was worth $1.50. The material was used for foundations, etc. Four men were employed. This stone was badly jointed, and could be handled



Fordham gneiss, showing foliation. Fort Field reservoir, Yonkers N. Y.



Gatehouse, Fort Field reservoir, Yonkers N. Y.
Built of Fordham gneiss



F. J. H. Merrill, photo.

Yonkers gneiss, Hastings N. Y.
Photomicrograph in polarized light, enlargement 22 diameters

in face of competition of the Yonkers gneiss quarries only because of shorter haul and the fact that removing the stone was raising the value of the lots.

Fordham, Westchester co. Fordham gneiss was formerly quarried (8) west of the Harlem railroad, south of Fordham, in the upper beds, much of the product being used for railroad ballast. It has also been quarried for road metal, for which purpose it is not well suited, at various points in Westchester county, but none of these small quarries are now working and none were ever of much importance.

Yonkers gneiss

The Yonkers gneiss is a well foliated gneissoid granite, very variable in color, grain, and economic value, but quite uniform petrographically. It is composed essentially of quartz, biotite, microcline, and sheared orthoclase. Normal orthoclase is not abundant, while plagioclase is very rare. Hornblende is the most common accessory, being very abundant in certain seams, and rarely entirely absent from a slide. Titanite is very frequent. A thin section is shown on pl. 48.

The color of the Yonkers varies from a light blue to a rather deep red. This variation is partly due to the fact that the blue grades in most cases contain more quartz and less feldspar. A much more potent cause, however, is that the feldspars themselves are either red or bluish. This difference in color is not due to a difference in the feldspar species, as the microcline and sheared orthoclase appear in both the red and blue Yonkers, and in about the same relative proportions.

The difference in color is of importance economically. The red forms decay readily while the blue, though often becoming stained yellow by iron, do not appear to disintegrate. The writer has not been able to follow up this investigation as far as he could have wished, and the discussion in this paper should be regarded as merely preliminary to a more detailed presentation of the subject.

The principal area of Yonkers gneiss is located in the southern part of Westchester county. It extends from near Van Cortlandt Park to Scarsdale, and occupies most of the ridge between the Bronx valley and the valleys of Tibbet and Troublesome brooks. Smaller areas occur northeast of White Plains, east of Hartsdale and at several other points mentioned below.

Most of the quarries in the main belt of Yonkers gneiss were opened around 1892. At that time an unusual amount of bridge and retaining wall work was being done by the Putnam, Harlem and New Haven railroads. Dimension stone and cut stone of smaller size was in great demand, and most of it came from the quarries in the Yonkers belt. This period of prosperity continued throughout 1892, 1893, 1894 and 1895. Since then the actual railroad demand has fallen off, and in addition, Palatine Bridge limestone is being used in place of the gneiss. During the "railroad" period it is probable that at least 100, possibly more, men were employed in the line of quarries running from Scarsdale to Dunwoodie. In 1899 about 15 to 20 quarrymen, with possibly 10 teamsters and teams, were employed. The year 1899 was, however, abnormally dull. The data quoted later may be taken as an average for the years 1896, 1897 and 1898.

Mr S. L. Cooper, commissioner of public works, city of Yonkers, wrote, in reply to an inquiry concerning the use of Yonkers gneiss by his department:

> The quarries you mention (Hackett, Cahill, O'Rourke) are the only ones now furnishing stone to the public works of this city. It is impossible to state with precision the amounts, but they have been about 2000 to 2500 cubic yards a year for the past three years. The contract prices depend largely on the length of haul. For macadam, telford stone and ordinary foundation or quarry-broken building stone, the price will vary from $1 to $1.50. For cut stone the price is about $40 a cubic yard for fine cut (8 cut) work. This is for cut-face and quarter-inch joints. Our local stone has been used for macadam only on the country roads, and the prices named above do not, of course, include the breaking of the stone to macadam size.

Since the decline of the railroad trade, the quarries depend largely on rough foundation stone, etc. to pay current expenses and fixed charges. This trade is, of course, very evenly distributed among the various quarries, as the difference in quality or price of this class of stone is not sufficient to give a decided advantage to any one quarry. Seely's quarry, at Scarsdale, is handicapped by greater distance from market, as little building is going on near it. Lowerre and Park Hill use a considerable quantity of this class of stone. A certain quantity of cut stone, about 2 feet by 2 feet by 18 inches in size, is used for private houses and for walls. This item is, however, of little importance.

The chief profit of the quarries comes from stone supplied to public buildings, schools, etc., for which a high grade of cut stone is required. Occasionally large semipublic buildings—hospitals, libraries, etc.—are erected, and to supply stone for these is almost as profitable.

As good trap and limestone can be obtained cheaply from the Palisades and Tomkins Cove, little stone is furnished by the local quarries for macadamizing. Occasionally, however, the Yonkers gneiss is used for this purpose on second class roads. The stone is then handbroken at the quarry, unless the buyer owns a crusher. Almost all of the so-called macadam roads are in reality telford roads, having a subpavement of large (5 to 8 inches) stone. The local quarries furnish most of this telford, using for it their worst grade, the coarse red Yonkers gneiss.

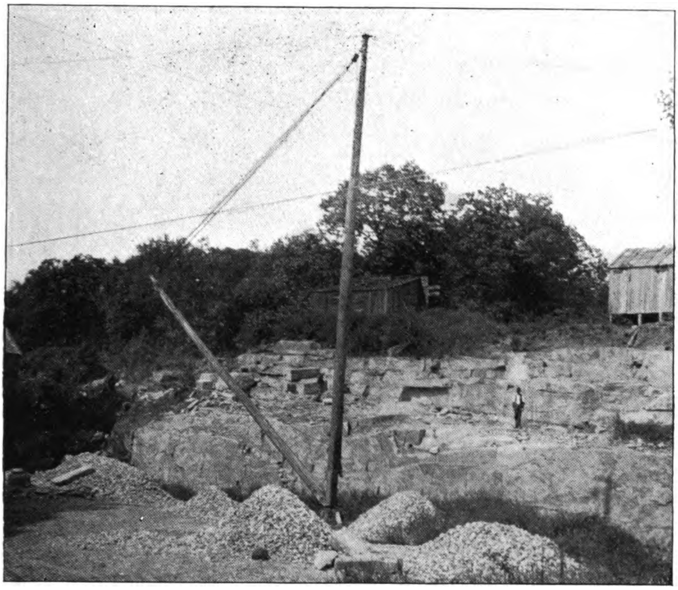
Scarsdale, Westchester co. *Seely's quarry* (19). Owned and operated by H. S. Seely. Several openings on the north side of Platt avenue, about half a mile west of Scarsdale station. The opening now worked is on the extreme west of the group, and has been worked for 100 feet along the strike. It is 30 feet wide and 10 to 20 feet deep, being entirely below the general ground level. A larger opening, on the extreme east of the group, shows an 8 foot bedded dike of a coarse-grained hornblende-feldspar rock. The average quality however, is very high; a large percentage of the material being the blue Yonkers. No machinery is on the ground, save one derrick—horse power. The product has, for five years or more, been only foundation stone. It will not exceed 150 cubic yards annually for which

$1 to $1.50 a yard (delivered) is obtained. Should a contractor wish to do his own quarrying a royalty of 25c a yard is charged. Selected and roughly trimmed stone brings $2 a yard. This quarry got a fair share of the railroad business but has been practically idle since that time.

Dunwoodie, Westchester co. *Hackett's quarries* (14). Worked and owned by Hackett Bros. of Dunwoodie. Located at the intersection of Central and Midland avenues, a mile or so northeast of Dunwoodie station. A small opening, with one derrick, is in the southwest angle formed by the intersection of the two avenues mentioned; the larger and older quarries are in the northwest angle. The quarry now worked has been opened for about 300 feet along the strike and about 80 feet across the strike. The foliation planes dip and strike n. 30° e., 85° w. One set of almost horizontal joints divides the rock into "beds" about 4 feet thick, while the set of joints parallel to the foliation are about 2 to 4 feet apart; and a third less important and regular set of joints strikes and dips n. 64° w., 75° w. Most of the quarry is above the ground level of its front. Stone from this quarry has been used in St Joseph's seminary, Dunwoodie, Seton hospital (Spuyten Duyvil), St John's hospital (Yonkers) and St Joseph's hospital (Yonkers), and in much railroad work, as well as in several Yonkers schoolhouses. In 1898 Hackett supplied some polished columns from this quarry for the county jail at White Plains. The polishing was done in New York city, and the columns are good samples of the best grade of the Yonkers gneiss. Four derricks (one run by steam, three by horse power) and one boiler are on the ground.

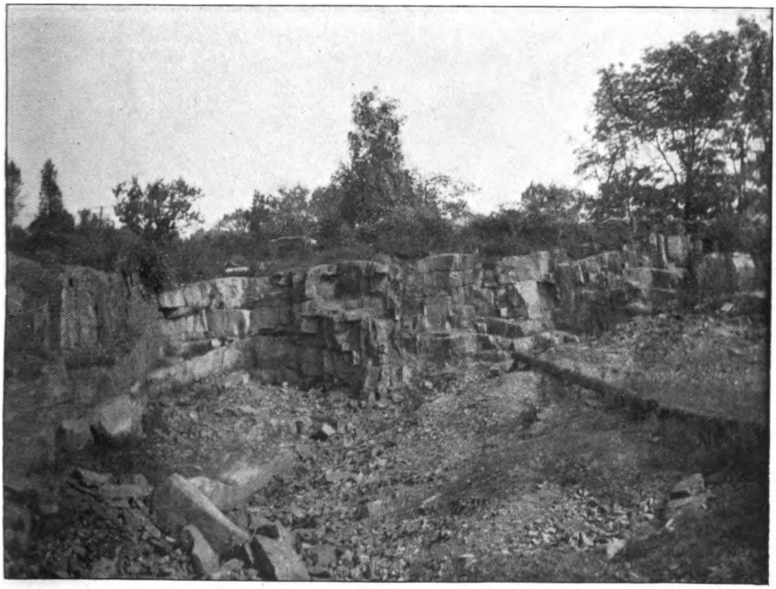
Mr Hackett estimates the annual product at 500 cubic yards macadam stone, 1000 cubic yards foundation stone and 100 cubic yards dressed stone. The main opening is shown on pl. 49.

Cahill's quarries (15). Owned and operated by Dennis Cahill of Yonkers. Situated on Midland avenue, several hundred yards east of Central avenue. The smallest and newest opening, at which a boiler is located, on the south side of Midland avenue, will probably be the principal quarry of the future. The



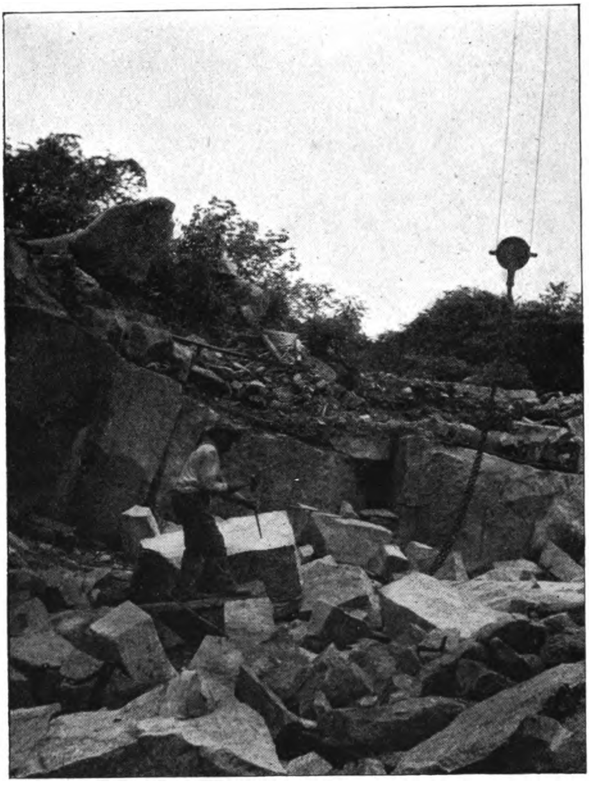
E. C. Eckel, photo.

Hackett's quarry, Dunwoodie N. Y.
(Yonkers gneiss)



E. C. Eckel, photo.

Flannery's quarry, Dunwoodie N. Y.
(Yonkers gneiss)



E. C. Eckel, photo.

O'Rourke's quarry, Dunwoodie N. Y.
(Yonkers gneiss)

larger openings are north of Midland avenue. The one now worked has been opened for a distance of 250 feet along the strike, and has been worked backward (toward the west) about 200 feet. The space worked out is filled up with waste rock. The foliation planes strike n. 22° e. and dip 70° to 90° w. One almost horizontal set of joints, dipping slightly to the east, divides the rock into 4 to 12 foot "beds." A less regular set strikes n. 65° w. and dips 67° w. One derrick is in use—horse power. Four quarrymen and a foreman are employed. The quarry was opened in 1892, and got much of the railroad work. Two schools were lately supplied, the cut stone being valued at about $5.50 a yard at the quarry. Smaller cut stone is sold, delivered, at about 30c a cubic foot. The annual product amounts to about 2000 cubic yards rough stone, valued at about 50c a cubic yard at the quarry; and about 100 to 200 cubic yards of dressed stone.

As in all the Yonkers gneiss quarries, black powder is used when necessary, but much of the stone can be gotten out by use of the plug and feathers. These are always used for splitting the stone to size after it has been broken out in blocks. The stone stands bush hammering well, and this is about the highest finish ever given it.

O'Rourke's quarry (17). Worked on lease by E. O'Rourke of Dunwoodie on land belonging to the Stewart estate. Opened for 65 feet along strike, 25 feet on dip, 15 to 20 feet deep. The opening is shown on pl. 50. Foliation places strike n. 32° e. and dip 66° e. The stripping was about 6 feet. Annual product about 1000 cubic yards foundation stone, at $1.75 a cubic yard, delivered, and 600 cubic yards cut stone, valued at $4000. This quarry shows a larger percentage of high grade stone than do any of the others. It was opened too late to get much of the railroad work, except the piers of the trestle at Lowerre, but gets a fair share of public and private work.

Flannery's quarry (13). This quarry was worked irregularly by the owner of the land, ——— Flannery. He is a builder and the product was used exclusively on houses which he built.

The quarry has been idle during recent years. The opening is about 100 feet long by 100 wide and 20 deep. The best stone, which is a very fair grade of Yonkers, is at the west side, the eastern side and center showing very thin-bedded stone. The quarry is shown on pl. 49.

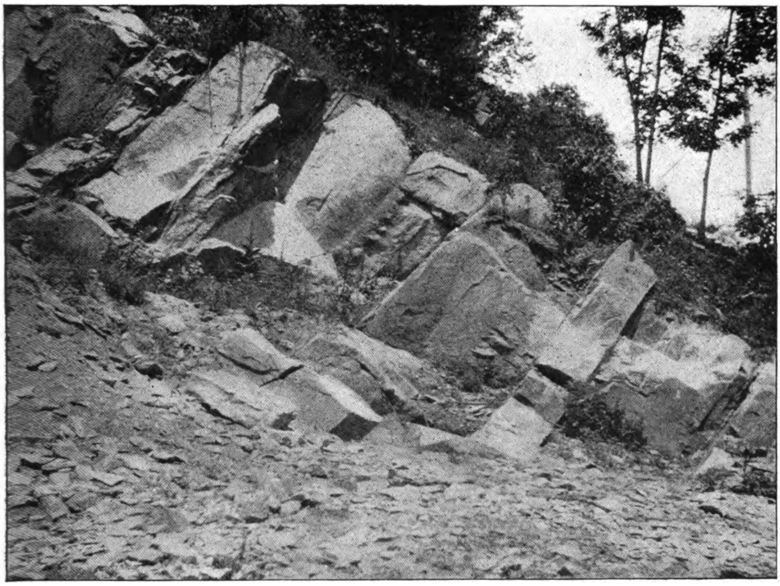
Valentine quarries (16). Several small openings exist nearer Dunwoodie. It is stated that these were worked eight or 10 years ago. This information, taken together with their location, makes it probable that they are the quarries described by Smock as the Valentine quarries and mentioned by Mather in 1843. At any rate, they are of historic interest as being the first quarries operated in the Yonkers gneiss belt.

Millwood, Westchester co. Quarries (24), formerly much worked for railroad ballast, occur at Merritt's Corners (Millwood), on the New York and Putnam railroad. The rock is a reddish gneiss, resembling some phases of the Yonkers gneiss. The foliation strikes n. 32° e. and is almost vertical in dip.

White Plains, Westchester co. Collin's quarry (22) is located about 1 mile northeast of Silver lake, the quarry being shown on pl. 51. The material shown in both the openings is a fairly well foliated reddish gneiss of the Yonkers type. It is heavy bedded, and the horizontal joints are far enough apart to permit the extraction of good sized blocks of stone. At present the local demand is insufficient to warrant steady working.

Hartsdale, Westchester co. McCabe's quarry (20) is situated about 1 mile east of Hartsdale station, in a narrow belt of Yonkers gneiss. The rock is of fair quality. Little has been used for structural work as rough stone; but a considerable quantity has been supplied for macadamizing roads in the vicinity. The material exposed is very light bluish in color and highly foliated.

Hastings, Westchester co. Rowley's quarry (23), situated a little east of the old aqueduct and a mile or less south of Hastings, is in a rock which may be considered Yonkers gneiss. Rowley's quarry was worked for a time to supply stone for a bridge on Warburton avenue. The stone obtained was too folded and dis-



E. O. Eckel, photo.

Collins's quarry, northeast of White Plains N. Y.
(Yonkers gneiss)

torted to be used for anything save backing and probably not over 500 cubic yards were used even for that. It is cut by three sets of joints—two approximately vertical, and one horizontal. They strike and dip respectively n. 37° e., 85° w.; n. 73° w., 80° e.; and n. 23° e., 20° w. Fragments of vein quartz, with faceted surfaces, were found on the dump, and several specimens of chalcopyrite were seen. Pegmatitic material also occurs. Much of the rock is highly micaceous and thin bedded, while the more solid portions are too much distorted to be used for face stones. The quarry will probably never be reopened.

Tarrytown, Westchester co. The old Beekman quarry (23a), on land belonging to the Kingsland estate, is located about 1 mile north of Tarrytown, near the Hudson river. It was formerly largely worked both for structural stone and, later, for railroad ballast. The material is a bluish to reddish gneiss similar in mineral composition to the Yonkers gneiss. Examples of it can be seen in several churches and other large buildings in Tarrytown. Gillmore reports a gneiss from Tarrytown, probably from this quarry, as showing in 2 inch cubes a compressive strength of 18,250 pounds a square inch, and as having a specific gravity of 2.655.

Ravenswood, Queens co. The eruptive area in Ravenswood L. I. (25), is composed of rock allied to the Yonkers gneiss but containing plagioclase in addition to the sheared orthoclase of the normal Yonkers. The occurrence of perthite in pegmatitic bands is noteworthy. It has been used to some extent in foundations, walls, and even buildings in the vicinity, according to my observations. Most of the area, however, falls within the limits of a public park.

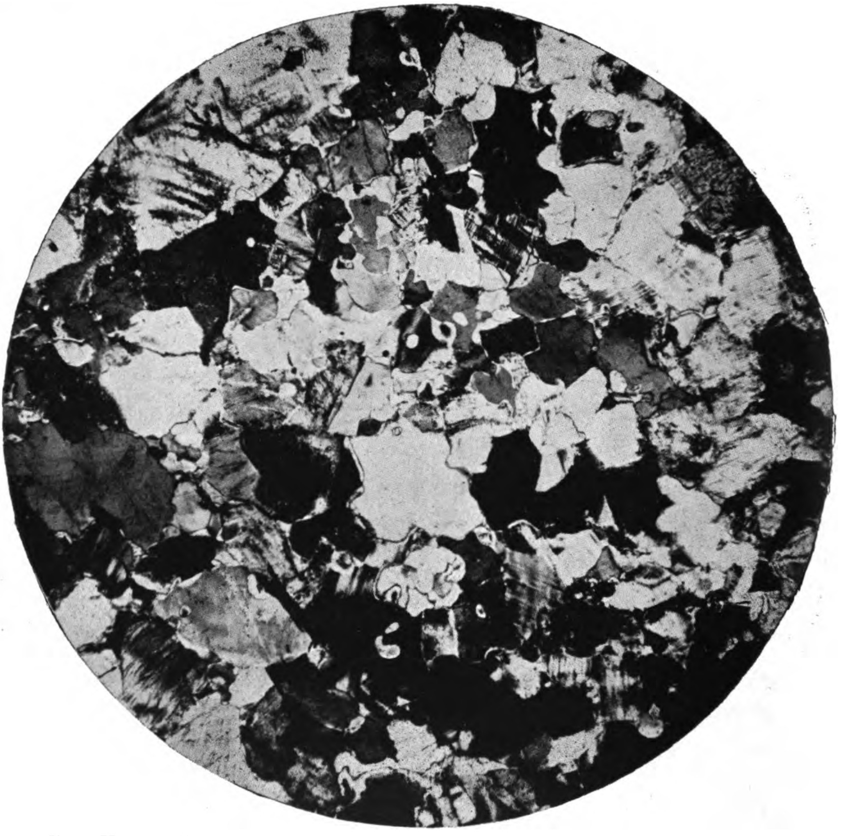
Granites and allied rocks in small areas

At many points in the area under consideration the members of the normal succession are cut by dikes and bosses of granites and granite-diorites. Coarse grained (pegmatitic) intrusives are of very frequent occurrence, particularly on and near Manhattan island, where such dikes are frequently shown cutting the Hudson schists. These materials are, of course, of no economic value. Finer grained granites occur, however, and are worked at several points within the area. Few of these quarries are so located with regard to water transportation routes as to be of more than local importance. The quarry most favored in this respect is King's, located near Garrison, Putnam co. Two quarries near Lake Mohegan, Westchester co., are of interest because of the importance of the works in which their product is used, as they supply respectively the new Croton dam at Quaker Bridge and the Cathedral of St John the Divine in New York city.

New Rochelle, Westchester co. *Ash's quarries.* Edwin Ash of New Rochelle works a group of small quarries (28) in the granite area northeast of that village. The poorer grade of stone is sold as foundation stone at 75c to $1 a load. The better grades he uses himself on monument work. The granite of this area is, in general, of very poor quality. It is often much foliated and contorted. Veins and pockets of pegmatitic material are scattered through it profusely. A slide showed feldspar, quartz in subordinate amount, biotite present but not in great quantity and a few large flakes of muscovite. The feldspars present were plagioclase, microline and orthoclase. Few minor accessories were present. The components noted above place this rock between the granites and the quartz diorites. The feldspars were much clouded. The stone is hardly suitable for building purposes for though the outcrops do not seem to be much disintegrated, yet the stone, in hand specimens or the mass, does not have a firm and durable appearance.

Mount Vernon, Westchester co. Fairchild's quarry (27) is owned by Fairchild Bros. of Mount Vernon. The quarry is an opening about 200 feet long (east to west), 60 feet wide and 35 high, situated on the southern face of a ridge near East Mount Vernon. The rock is a bluish, very tough and compact granite. Slides show microline to be the predominant feldspar, with some orthoclase and a little plagioclase. Muscovite is in long coarse flakes and biotite in smaller flakes are present in

Plate 52 To face p. r163



F. J. H. Merrill, photo.

Granite, King's quarry, near Garrisons N. Y.
Photomicrograph in polarized light, enlargement 22 diameters

about equal quantity. The grain is small and the feldspars fairly fresh. The rock is so thinly and irregularly jointed that it is not much used for building stone. Even with great care, not over 5% to 10% of the total product could be gotten out in large enough blocks to use for structural purposes. At present it is crushed at the quarry and sold for local use as macadam. A 40 horse power boiler runs the drills (McKiernan) and a Brennan crusher (18 horse power engine). The crusher can turn out 50 to 65 yards of crushed stone a day. The stone was first used in building macadam roads in 1891. It was found that the granite does not grind up into impalpable dust as does trap or limestone but in dry weather loosens up into a heavy dust about the character of coarse sugar, and on being watered packs down again into a hard road. The roads in their wearing quality have exceeded expectations, particularly where the road-bed was on wet soil. The white color of the road is somewhat objectionable during the summer on account of the glare.

Lake Mohegan, Westchester co. Intrusive granites are being extensively quarried at two points about 1 mile south of Lake Mohegan. All the product of both quarries is used as cut stone, that from the northern quarry (30) in the new cathedral (St John's) in New York city, while that from the southern quarry (29) is used on the new Croton dam at Quaker Bridge. The stone is a yellowish to pinkish, medium grained granite, discolored in places apparently by decay of its contained biotite.

Garrisons, Putnam co. King's quarry (31) is located about 2½ miles south of Garrisons, Putnam co., and ¼ mile east of the Hudson river. It is owned by the King granite co. and is at present operated under lease by Doern & Sons of New Rochelle N. Y.

The opening is about 300 by 200 feet in area and 50 feet deep. Little water is encountered. The rock is a fine grained, light gray granite, intrusive in the pre-Cambrian gneiss, and is shown in section on pl. 52. The main set of joints strike nearly north and south, and dip about 70° to the east. A prominent horizontal series of joints divides the rock into "lifts" from 1 to 8 feet thick.

Black powder is used in blasting, the holes being put in by Ingersoll steam drills, three of which are in use. Three derricks are in place at the quarry. By means of these the stone is lifted to the ground level and run on little trucks down a tramway to the dressing sheds. Little polished stone is sold, the greater part of the product being patent hammered. 10 cut work is the finest done; 6 cut is about the average finish. At present no paving blocks are made up. 35 to 40 men are employed through about 10 months of the year, in the quarry, dressing sheds and loading. The quarry and dressing sheds are shown on pl. 53.

From the dressing sheds the stone is transported by wagon to the river where a derrick is used in unloading it from the wagons and placing it on the scows.

Among the buildings recently erected of stone from this quarry are a church and a school building at Tarrytown, St Joseph's church (Tremont av. and Washington st. New York), the powder magazines at Iona Island and the guardhouse at West Point.

Round island, Rockland co. A granite quarry (31a) operated by Daniel E. Donovan on Round island has furnished large quantities of road metal.

The chemical composition of this granite is shown by analysis[1] to be:

	%
$Si\,O_2$	63.19
$Al_2\,O_3$	10.51
$Fe_2\,O_3$	10.97
$Fe\,O$	1.51
$Ca\,O$	6.12
$Mg\,O$	1.44
$K_2\,O$	4.02
$Na_2\,O$	1.92

Pine Island, Orange co. Granite quarries have been operated on Mt Adam (33), Mt Eve (34) and Pochuck mountain (32).

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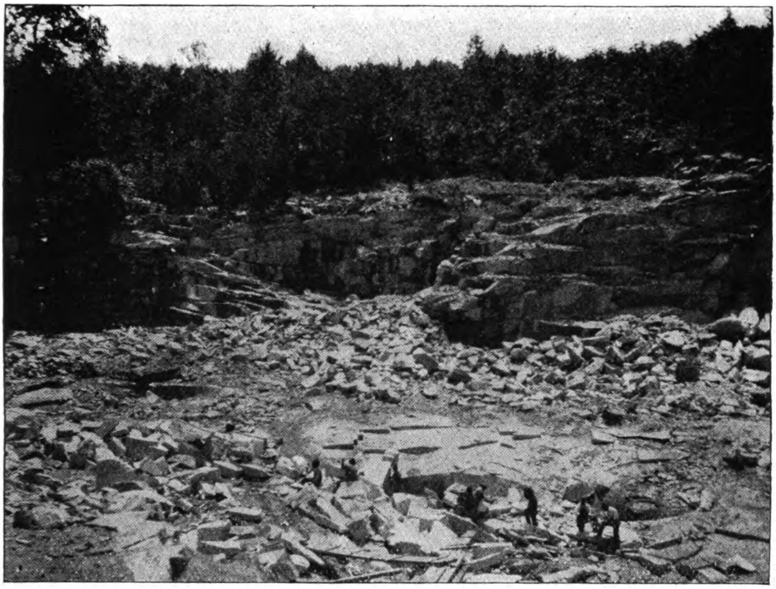
[1] U. S. geol. sur. 20th an. rep't. Pt 6, continued, p. 421.



E. C. Eckel, photo.

King's quarry, near Garrisons N. Y.
(granite, intrusive in the pre-Cambrian)

E. C. Eckel, photo.

Dressing sheds, King's quarry, Garrisons N. Y.

The granite quarried by the Pochuck granite co. was tested[1] by Prof. J. P. Carlin, with the following results.

Compression tests of granite

No.	Size of cube in inches	Area	First crack at	Ultimate strength	
				Total	per sq. inch
1	2.02 by 1.98 by 2	4 sq. in.	66 500 lb	94 000	23 500
2	2 by 2.1 by 2	4.2 sq. in.	74 000 lb	96 000	22 900

Harrison diorite

The Harrison diorite is a medium grained granite diorite, containing typically quartz, plagioclase (with subordinate orthoclase and microcline) and biotite. In Westchester county it covers a large part of the towns of Mamaroneck, Rye and Harrison, and the same area extends eastward into Fairfield county, Ct. as far as Stamford. In the New York portion of the area it is intrusive in the Hudson schist.

In that part of the Harrison diorite area which falls in Westchester county the diorite is generally highly foliated and often somewhat disintegrated on the outcrop. It is only quarried at one point in the area, which is described below. Several Connecticut quarries are also noted.

Larchmont, Westchester co. Campbell's quarry (35) is owned and operated by W. H. Campbell of Larchmont. All the product so far has been used on buildings erected by Mr Campbell. The quarry has been worked for about four years, and the total output is estimated at 4000 cubic yards. This is all used as dressed stone (bush hammered). The stone is of good quality. It is not much foliated, and has a rather pleasant bluish color. It is said to stand dressing well. In addition to the quartz and plagioclase, however, it contains much biotite and numerous garnets about $\frac{1}{8}$ inch in diameter. Sheared orthoclase is very infrequent. In a slide the feldspars are seen to be somewhat clouded but the biotite is very fresh.

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[1] U. S. geol. sur. 20th an. rep't. Pt 6, continued, p. 421.

East Portchester, Fairfield co. Ct. A small quarry (36) in Harrison diorite is worked by Antonio D. Parlo & Son near the corner of Henry st. and Bridge st., Port Chester. This quarry is on the Connecticut side of the line but is included here for completeness. The total product is probably less than 500 cubic yards a year, including macadam, rough stone and a small amount of bush-hammered (patent hammered) stone. A granite dike about 10 feet wide cuts the diorite near the opening and material from it is occasionally used by the above firm.

Greenwich, Fairfield co. Ct. Large quarries (37) in the Harrison diorite are located just south of the New York, New Haven & Hartford railroad tracks, between Port Chester N. Y. and Greenwich Ct. The diorite is here much more massive than in the New York portion of the area and has long been valued as a building stone. The facilities for shipping are excellent, the quarries being almost at the water's edge. The diorite area extends to near Stamford, and small quarries (38) occur at several points within its boundaries.

Cortlandt series: gabbro and diorites

The dark colored, basic rocks of the Cortlandt series cover an area of about 20 square miles in the towns of Cortlandt and Yorktown, Westchester co. Much of the material is suitable for use as macadam, but unfortunately the best material is not near the Hudson river. Much stone has been quarried (39) near Quaker Bridge, Westchester co., for use in the new dam across the Croton river. This rock has been reported on by Prof. J. K. Kemp. An analysis[1] made for him by H. T. Vulté, follows:

SiO_2	54.72
Al_2O_3	17.79
Fe_2O_3	2.08
FeO	6.03
CaO	6.84
MgO	5.85
Na_2O	3.02
K_2O	3.01

The specific gravity of the above rock is stated[1] as being 2.928.

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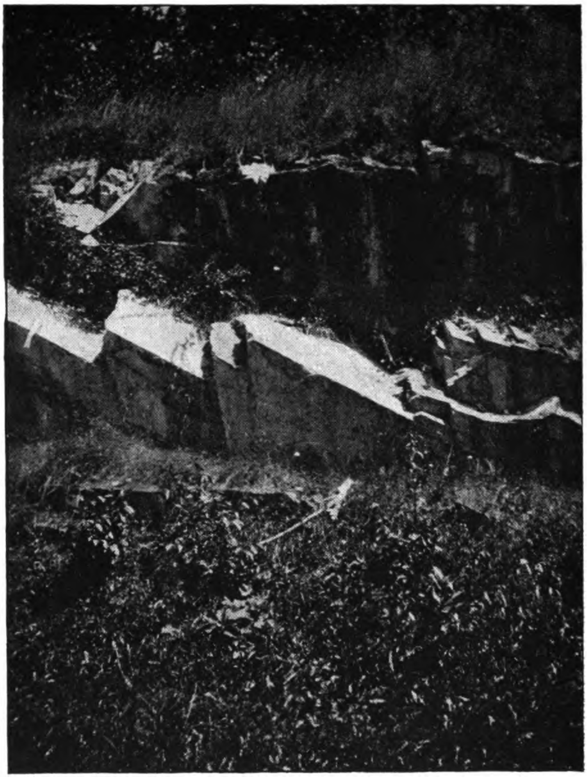
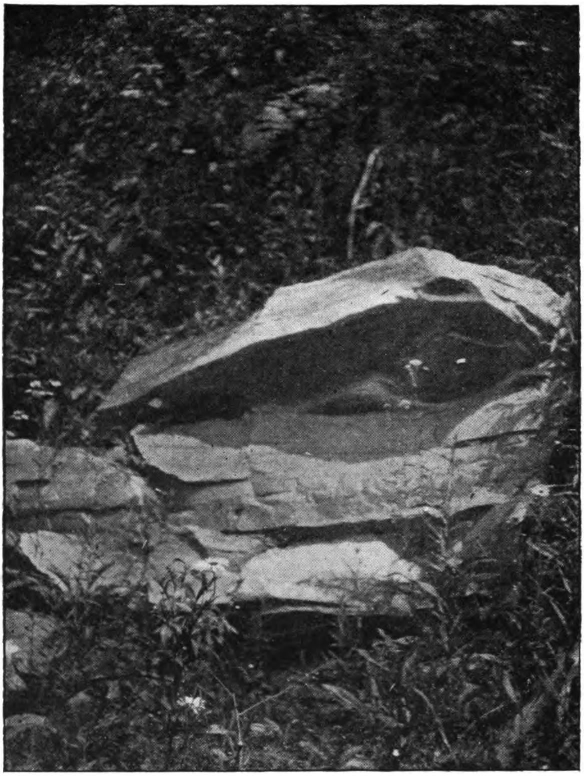
[1] Kemp. Handbook of rocks. Ed. 2. 1900. p. 49.



E. O. Eckel, photo.

Poughquag quartzite, Peekskill Creek, showing slaty cleavage



E. C. Eckel, photo.

Quarry in Poughquag quartzite, near Adams Corners, Putnam co. N. Y.

A mica diorite of the Cortlandt series was tested[1] for compressive strength, crushing at 20,250 lb a square inch.

Newark diabase

The "trap" of the Newark system has been long known as a valuable road metal. Large quarries (40) in this rock are located north of Nyack, Rockland co.; while a quarry (41) has been recently opened near Mt Ivy, Rockland co. Tests of material from several of these quarries will be found recorded on p. r14–r22 of this volume.

SANDSTONES: INCLUDING SHALES

Poughquag quartzite

In Westchester county the Poughquag quartzite is a very hard and compact siliciously cemented sandstone, occurring at the contact between the Fordham gneiss and Stockbridge limestone. The formation has a thickness of at least 30 feet near Hastings but thins out on going south or east. The rock is prevailingly light colored and very evenly and thinly bedded, the slabs varying usually from ¼ inch to 2 inches in thickness. This, with the closeness of its jointing, usually prevents even moderate sized blocks from being obtained. The rock therefore, though highly durable, is of little economic importance. It has been used however as coping for a retaining wall on Warburton avenue near Hastings. At this point it was obtained in slabs about 4 feet by 3 feet by 3 inches and makes an ideal coping.

Near Adams Corners in Putnam county is a small quarry in this formation (43). One of the openings, now almost hidden by vegetation, is shown on pl. 55. The product was used for furnace lining.

Hudson shales and sandstones

Prof. William B. Dwight states that in Dutchess county the sandstone of the Hudson formation is everywhere fine grained and very irregularly bedded; and that it is of only local use as building stone. Quarries in the thicker beds have been worked near Highland, Ulster co.; and the shales of the formation have been quarried to some extent in Orange county for use as road metal.

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[1] Newberry. School of mines quarterly, July 1887.

Green Pond conglomerate

Central Valley, Orange co. The Green Pond conglomerate has been used to a small extent for foundation and wall stone. The small bridge, one arch of which is shown on pl. 56, is located near Central Valley, Orange co. and was built under the direction of Mr Richard Ficken from blocks of Green Pond conglomerate. Used in the manner shown, it is a decidedly attractive material and much preferable to the rough dressed limestones so often used for similar bridges and walls.

Pine Hill quartzite

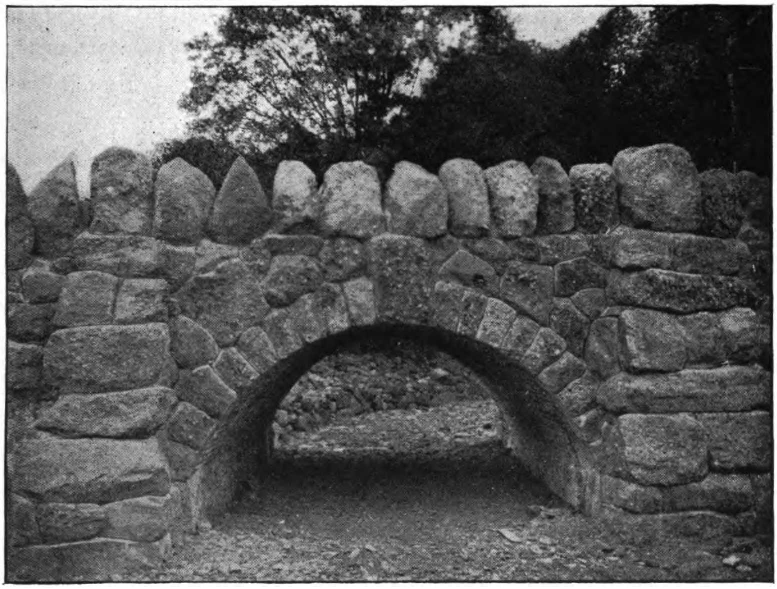
The white and red quartzites of the Pine Hill formation are well exposed along the crest and at the southern end of Pine hill. They have been little used, as their hardness makes dressing difficult. It is probable that they could be profitably exploited, and that stone of this quality and color would find a ready market in New York city.

Longwood red shales

Highland Mills, Orange co. Several quarries (46) in this formation along the west side of Pine hill, near its southern end, are worked rather extensively. The red shales are used on most of the roads in the neighborhood, and, for light traffic, are an admirable road metal. Under heavy traffic, however, specially in wet weather, they grind up into a fine stiff clay.

Bellvale flags

Monroe, Orange co. Two quarries in the Bellvale flags are near Monroe. The first, the Davison quarry (45), is located near the Seven Springs Mountain house; the second, that of O. H. Cooley (44), is nearer Monroe. The beds worked at both quarries are thin and irregularly bedded flagstones, gray in color, and with much waste material. The quarries have, however, furnished a considerable amount of material for local use as steps, curbing, flagging, etc., as no other material suitable for these purposes occurs in the vicinity.



E. C. Eckel, photo.

Arch of bridge near Central Valley, Orange co. N. Y.
Built of Green Pond conglomerate

Newark sandstone

Nyack and Haverstraw, Rockland co. The reddish brown sandstones of the Newark system were formerly quarried (47) extensively in Rockland county. At present the product is still of some importance, but is used locally only.

LIMESTONES: INCLUDING MARBLES

Cambro-Silurian (?) limestones of the Highlands

Several of the areas of white limestone in the Highlands of Putnam and Orange counties have been worked for lime; a few have furnished stone for local building purposes. The only quarry of sufficient interest to warrant notice here is described below.

Cold Spring, Putnam co. Heustis's quarry (49), which has not been worked for many years, is located about 4 miles northeast of Cold Spring, Putnam co. The product, a serpentine marble, was obtained from an outcrop of limestone on the western bank of a small brook. In the brook thin bedded quartzite appears. As both limestone and quartzite can be traced, though with frequent breaks, to the northward, till the valley opens out into the great Paleozoic plain of Dutchess county, it seems probable that they are merely very highly crystalline representatives of the Stockbridge limestone and Poughquag quartzite respectively. At Heustis quarry the marble is heavily charged with silicates, whose presence may be attributed to the intrusion of a dike of red granite which outcrops near the quarry. The serpentinous portions of the marble are not sufficiently large or firm to warrant exploitation and the quarry is merely of historic interest.

Stockbridge and Barnegat limestones

The Stockbridge limestone was formerly highly esteemed as a structural stone, and many quarries worked it for such use. Of late years, however, its popularity has declined, and only one limestone quarry is now producing building stone in the area under discussion.

The rock is, however, of great value for other purposes. In its less crystalline condition (as shown at Tomkins Cove and Stoneco) it is very important as a source of road metal. A number of quarries are still working, but only one produces building stone. The others crush the material, either selling it as marble dust, for use in the manufacture of carbonated waters and also in asphalt paving mixtures; or burning it into lime, to be used for chemical or structural purposes. Wherever a magnesia lime is serviceable, the product of these quarries can be utilized. In early times lime was burnt at several points between Yonkers and Lowerre, as well as north of Spuyten Duyvil, several old kilns still being visible near the Hudson river.

Tuckahoe, Westchester co. *Norcross Bros. quarry.* This, the northernmost (53) of the principal quarries at Tuckahoe, was opened in 1854. It was worked by A. Maxwell, then by A. T. Stewart, and is noted in Smock's report as the Stewart quarry. It is now operated by Norcross Bros. under the superintendency of Mr J. M. Masterton. The quarry is opened for a distance of about 600 feet along the strike and is 150 feet wide and 70 deep. No lime is burned and all the product is marketed as dressed stone. During the entire time of its working, the maximum annual production was about 60,000 or 70,000 cubic feet. During late years the principal buildings supplied were the Home Life (rebuilding), the Clark mansion (80th st. and Riverside drive), and the New York Life—all in New York city.

Three boilers are in service—one 100 horse power in the mill, and an 80 horse power and 50 horse power in the quarry. The water is obtained from a spring in the quarry and requires no treatment. An air compressor is used, which runs the drills and the pneumatic tools in the mill. The compressor, drills, quarry-bar and gadders are Ingersoll-Sergeant; the six channelers are Sullivan. In the mill are seven gangs of saws, four planers, three turning lathes and three rubbing beds.

The dip is steep, 70° or so to the west. In the more openly bedded parts of the quarry wedges are used to separate the slabs. In closely bedded parts channelers make cuts 12 feet deep and 2 inches wide, on the dip. These cuts are put in about 42 inches apart. Gadders or drills mounted on quarry bars are then used to put in rows of horizontal holes at right angles to the strike. Wedges in these holes release the stone in slabs of the desired size. Powerful derricks then lift the blocks to the level of the mill. After dressing it is sent down a side track to the Harlem railroad above Tuckahoe. No explosives are used.

Tuckahoe marble company's quarry. This (52) is next south of the above, is idle now, and has not been worked for five years or more.

New York quarry co. This quarry (51) is the southernmost of the Tuckahoe quarries and was formerly known as the Masterton quarry. One of its two openings is idle, the other and larger is worked under lease by O'Connell & Hillery, the stone being crushed for "marble dust" or burned into lime. The rock is blasted, hammer-broken into pieces of convenient size and carried by cableway to the kilns.

Analyses of the stone from the O'Connell and Hillery quarry follow. Several of these have been erroneously quoted in different state and federal publications, the analysts' names being given incorrectly and the analyses being referred to the Norcross quarry.

	1	2	3	4
$Si\ O_2$	....	2.4	....	.24
$Al_2\ O_3$	....	2.15	....	.19
$Fe_2\ O_3$	.21		....	.21
$Ca\ CO_3$	....	83.36	70.1	....
$Ca\ O$	30.68	....	....	30.16
$Mg\ CO_3$	....	12.09	25.4	....
$Mg\ O$	20.71	....	....	21.25
CO_2	46.66	....	....	47.3
Insoluble	1.33	....	....	....

1 W. F. Hillebrand, analyst, 1887.
2 H. L. Bowker, analyst, 1894.
3 17th an. rep't U. S. geol. sur. pt 3, p. 796.
4 P. de P. Ricketts, analyst, 1887.

White Plains, Westchester co. A quarry (57) has been opened in the Stockbridge limestone just west of the tracks of the New York and Harlem railroad and about 1 mile north of White Plains. It is operated by James O'Connell. All the rock quarried is burned into lime or used as crushed limestone. Views at this quarry are shown on pl. 57 and 58. An analysis of the limestone, made by Huntington in 1899 follows:

$Si\,O_2$	2.08
Al_2O_3 and Fe_2O_3	.56
$CaCO_3$	58.72
$Mg\,CO_3$	37.79
(Available CO_2	45.57)

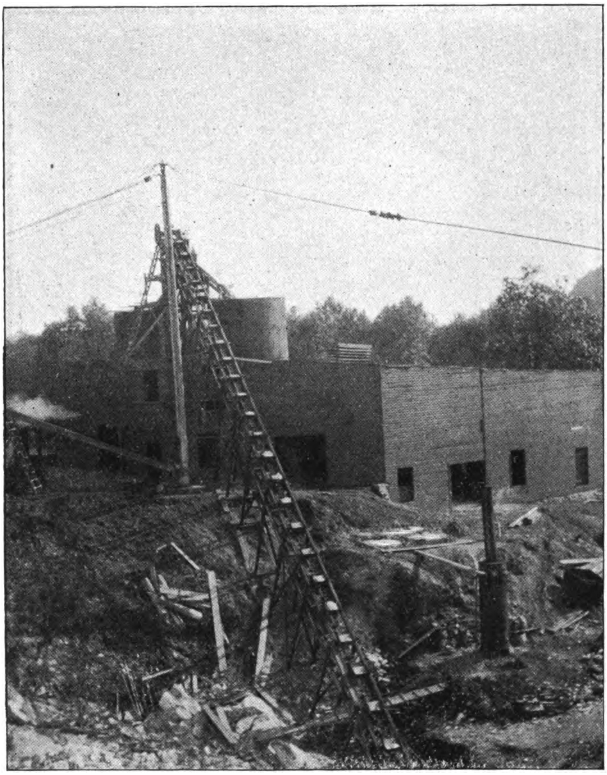
Hastings, Westchester co. At Hastings the old quarry (55) is unworked, and is merely of historic interest. West of the old Croton aqueduct a quarry was opened in a thin bedded and brownish limestone, very micaceous. The product was intended for the asphalt blocks of the Hastings paving co. but proved unsatisfactory.

Pleasantville, Westchester co. Several large quarries (58) in the Stockbridge limestone are located south of Pleasantville, near Unionville station. The product has been largely used, both for structural purposes and for burning into lime. The marble from these quarries is coarser grained than that from Tuckahoe, and lost public favor earlier. The lime quarries and kilns, however, have been worked till lately. Analyses of Pleasantville limestone follow:

	1	2	3
$Si\,O_2$	2.31	.1	.29
$Al_2\,O_3$	.49	.07	....
$Fe_2\,O_3$	.25	.16	....
$CaCO_3$	59.84	54.62	54.8
$MgCO_3$	36.8	45.04	43.11

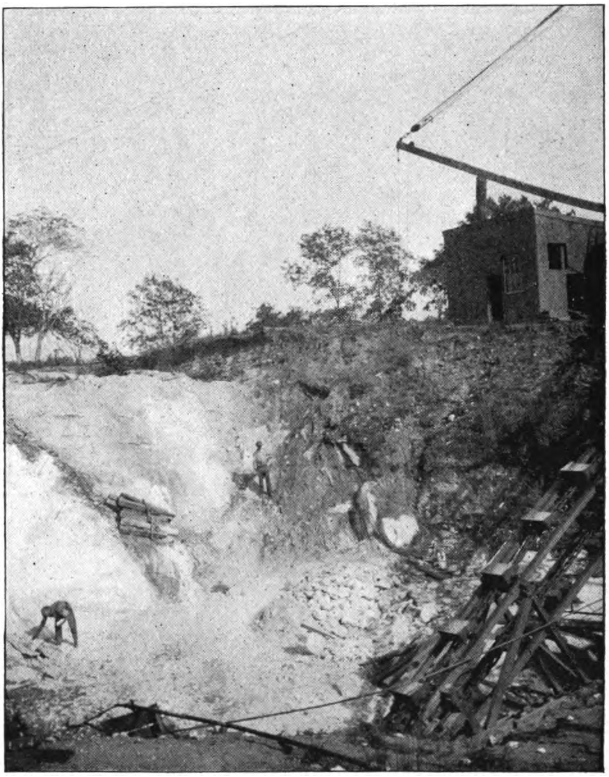
1 H. Ries, analyst, N. Y. state mus. 51st an. rep't, p. 466.
2 "Columbia college," U. S. geol. sur. 16th rep't, pt 3, p. 468.
3 Wilber, analyst, N. Y. state mus. Bul. 10.

Ossining, Westchester co. Marble was formerly quarried on land belonging to the state near Ossining. The following anal-



E. C. Eckel, photo.

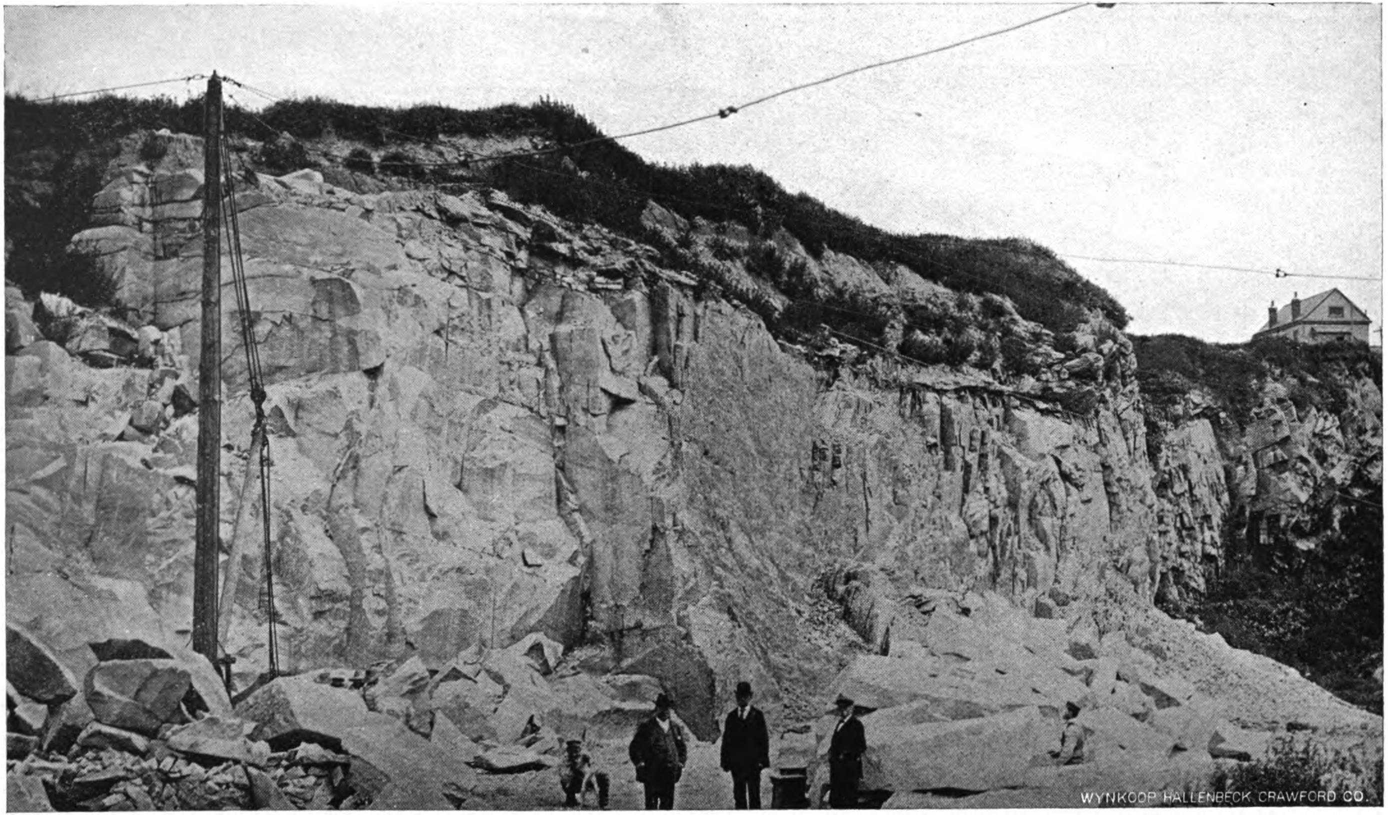
O'Connell's quarry, near White Plains N. Y.
View of elevator, kilns etc.
(Stockbridge limestone)



E. C. Eckel, photo.

O'Connell's quarry, near White Plains N. Y.
View of main opening
(Stockbridge limestone)

Plate 59



H. Ries, photo.

Marble quarry, Ossining, Westchester co. (Stockbridge limestone) ysis of "marble from Sing Sing," is given by L. C. Beck[1] and apparently is of material from this quarry.

$CaCO_3$	53.24
$MgCO_3$	45.89
SiO_2, AlO_3, Fe_2O_3	.87

Two large quarries (60, 61) in the Stockbridge limestone have long been worked near Ossining, part of the product being shipped for use as flux and part being burned into lime. These quarries are worked by Henry Marks and the Sing Sing lime co., respectively. Analyses[2] of the rock follow.

SiO_2	.98	.87
Al_2O_3	.84	.57
Fe_2O_3	.3	.25
CaO	31.4	31.4
MgO	16.96	19.95

Oscawana, Westchester co. Tat's quarry (65) is located about 2 miles northeast of Oscawana station. Very little stone has been taken out and the opening is not at present worked. The product is a very white and very fine grained marble. The quarry could not be closely examined when visited, as the opening was filled with water, but if blocks of large size can be obtained the product should be readily marketable, as the quality is excellent, so far as color and grain are concerned.

Bedford, Westchester co. Several small quarries (62) east and northeast of Bedford in the Stockbridge limestone, were formerly worked, the product being burned into lime for local use.

Armonk, Westchester co. Quarries just north of the Connecticut line were formerly worked rather extensively, all the product being burned into lime.

Golden's Bridge, Westchester co. Todd's quarry (64) is situated about 3 miles east of Golden's bridge. It is a small quarry, in a rather highly contorted limestone, and has not been worked for the past 10 years. The stone does not appear to be fit for cutting, though a mill is located near the opening.

Marble has been quarried at Patterson and Towners (66), Putnam co.; but the product was not large and the quarries have been idle for some years.

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[1] N. Y. geol. sur. 3d rep't. 1839. p. 19.

[2] Ries. N. Y. state geol. 17th an. rep't. 1899.

South Dover, Dutchess co. The South Dover marble co. operates a large quarry (67) about 2 miles northeast of Wing station. The product, all of which is used for structural purposes, is carried to the railroad at Wing on an electric trolley road built by the company for that purpose. An analysis of the marble made by Ricketts and Banks follows:

SiO_2	.7
Fe_2O_3	.25
Al_2O_3	.37
CaO	30.63
MgO	20.25
Na_2O	.12
K_2O	.46

Dover Plains, Dutchess co. This quarry was not visited by the writer, and the following description is therefore quoted from Ries.[1]

> At Dover Plains, G. & J. H. Ketcham have operated a quarry along the highroad ½ mile southeast of the town. The rock is a soft, fine grained dolomite of gray or white color. The opening is about 200 feet long, 20 to 30 feet wide and 10 feet deep. No analysis was made of the stone but several samples were examined to determine their insoluble matter, which ran from 2 to 3 per cent.

Small marble quarries have been operated at several other points in eastern Dutchess county, notably near Pawling and Dover.

Stoneco, Dutchess co. Large quarries (68) in the blue silicious limstone have been opened on Clinton point, on the east side of the Hudson river, north of New Hamburg. These quarries are operated by the Hudson River stone supply co. All the product is used as road metal, to which use it is particularly well adapted. Samples from these quarries have been tested for binding power, wear, etc., and the results of these tests will be found reported on p. r14–r22 of this volume.

Ries gives the following analysis of the limestone from Clinton point.

SiO_2	10.17
Al_2O_3	2.33
Fe_2O_3	.47

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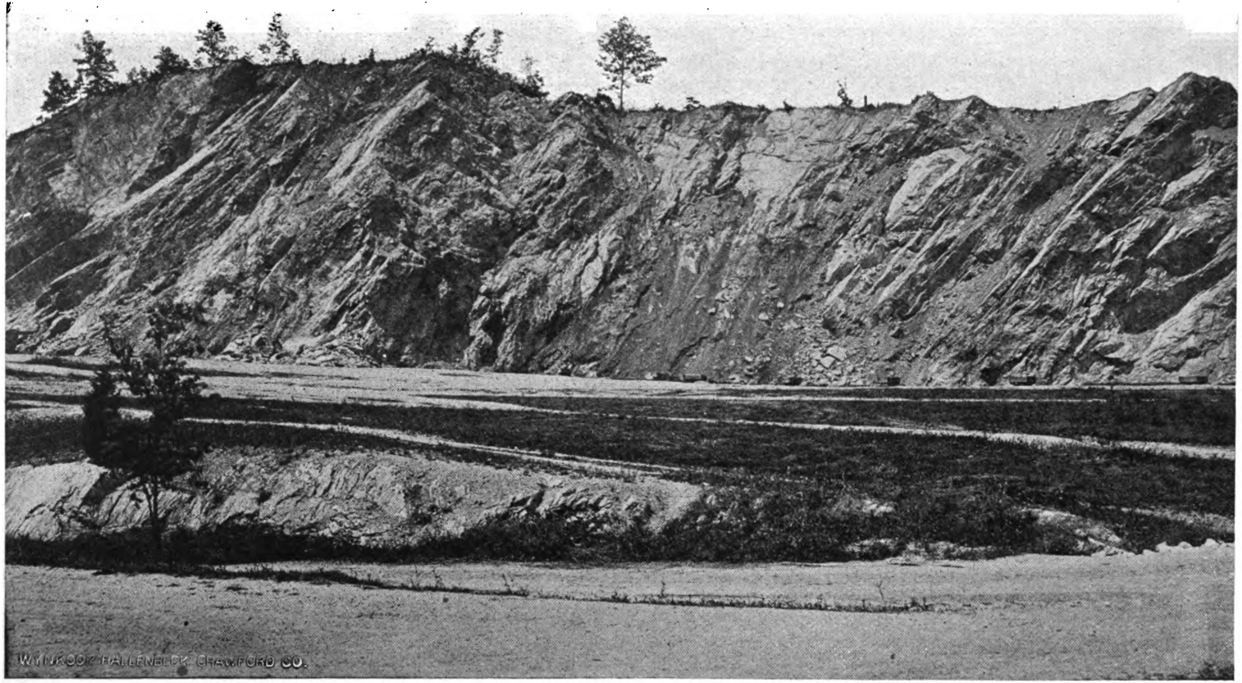
[1] Ries. N. Y. state geol. 17th an. rep't. 1899.

Plate 60

To face p. r175



H. Ries, photo.

Limestone quarry, Tomkins Cove, Rockland co. (Stockbridge limestone)

CaO	29.07
MgO	16.29
CO_2	40.76

Tomkins Cove, Rockland co. The Tomkins Cove stone supply co. operates extensive quarries (78), shown on pl. 60, at this point on the west shore of the Hudson river. The material quarried is a light blue, silicious limestone of the Stockbridge formation. The entire product, which is very large, is used for road metal. Ries[1] gives the following analysis:

SiO_2	12
Al_2O_3	4.13
Fe_2O_3	1.05
CaO	26.34
MgO	16.74
CO_2	39.1

Newburg, Orange co. Miller's quarry (72) is located southwest of Newburg on the flank of Snake hill. The product, a blue magnesian limestone, is mostly burned into lime, though also used locally for structural work.

An analysis of the limestone from Miller's quarry is given by Ries.[1]

SiO_2	10.46
Al_2O_3	1.93
Fe_2O_3	1.8
CaO	27.75
MgO	17.65
CO_2	40.99

Roseton, Orange co. A small quarry (79) in the blue Barnegat limestone near Roseton has been worked irregularly but is not at present producing.

Newburg Junction, Orange co. The limestone quarry (69) just east of the railroad at Newburg Junction, Orange co., shows Cambro-Silurian blue limestone, with interstratified black and yellow shales. Pre-Cambrian gneiss is shown on the upper edge of the eastern wall of the opening. The quarry is not at present worked but has supplied a considerable amount of material both for lime and flux. It is possible it will furnish macadam for roads in the vicinity.

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[1] Ries. N. Y. state geol. 17th an. rep't. 1899.

Johnsons, Orange co. A small quarry in the blue limestone, situated about 2 miles north of Johnsons, in the town of Wawayanda, is worked at intervals for stone and lime. The quarry is located on land owned by S. M. House, and is worked by Wilber Brown. Most of the product is burned into lime and used locally.

New Milford, Orange co. Several small quarries in the Barnegat limestone are located within a few miles of New Milford. They are worked only at intervals, and the product is chiefly used for foundation stone.

Monroe, Orange co. A small quarry (70) has been worked about a mile south of Monroe. The product was used locally for foundation and retaining wall work.

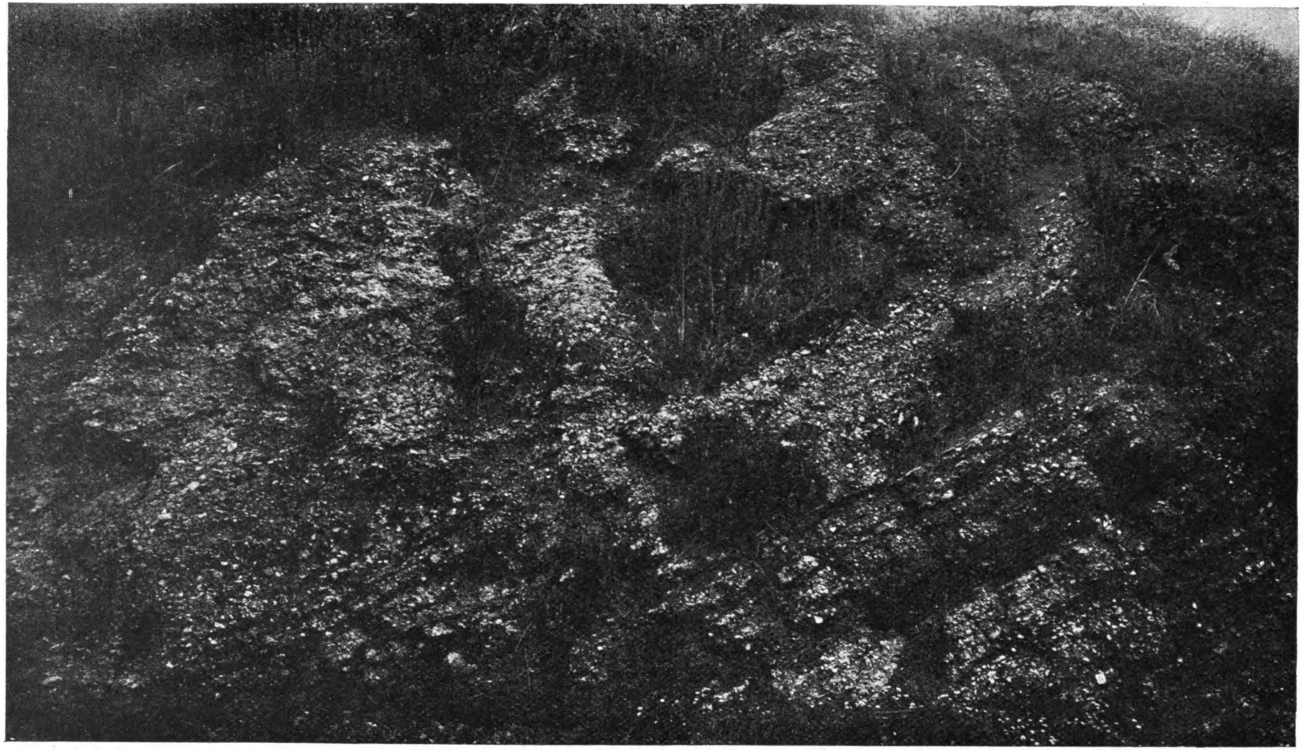
Warwick, Orange co. Limestone is quarried near Warwick by Thomas Burt. The product is small, the quarries being worked only at intervals, and is mostly used for structural work. It is the usual blue magnesian (Barnegat) limestone.

Newark limestone conglomerate

Along its contact with the pre-Cambrian and Paleozoic rocks, the lower beds of the Newark system are frequently conglomeratic. In certain localities the included pebbles are limestone, and in a few places the calcareous portion of the conglomerate is so much larger in amount than the shaly matrix as to permit the use of these rocks for lime. A characteristic exposure of this conglomerate is shown on pl. 61. Several old quarries (80, 81) are located in Rockland county along the northern border of the Newark beds, and lime was formerly burned at these points.

Plate 61

To face p. r176



H. Ries, photo.

Newark conglomerate, Stony Point, Rockland co.

RECENT DEVELOPMENTS IN THE GYPSUM INDUSTRY IN NEW YORK STATE

BY ARTHUR L. PARSONS

Gypsum deposits of Fayetteville

The quarries at Fayetteville are located about 2 miles southwest of the village and are situated on two knolls.

Five companies have quarries here: the National wall plaster co. and the Adamant wall plaster co. of Syracuse, Mr F. M. Severance, Mr C. A. Snooks and Mr C. Snooks of Fayetteville. The latter two have small quarries.

The oldest quarry is that of Mr Severance, which has been worked more than 60 years. The bed of gypsum in this quarry is about 60 feet thick and consists of eight layers varying in thickness from 18 inches to 30 feet. It is covered with about 40 feet of shaly rock, together with hydraulic limestone.

The plaster rock varies in color from light drab in the cap to a dark brown (iron layer), all forms becoming lighter on exposure to air. The so-called "slate" consists of fibrous, scaly, and other forms of gypsum; the remaining beds consist almost entirely of compact gypsum.

The specific gravity varies from 2.68 in the 9 foot layer to 2.33 in the slaty layer.

The composition is nearly uniform, consisting of calcium sulfate, 80% to 90%; calcium carbonate, a trace; magnesium carbonate, 5% or less; alumina, 10% or less. The amount of carbonates is greatest in the iron layer, showing effervescence in the mass. It is nearly as abundant in the cap layer; it is least in the crystalline layer (the so-called "slate"). In none of the layers is the quantity sufficient to prove detrimental. To quarry this gypsum, the slate rock above must be stripped. This stripping is accomplished after a portion of the quarry has been worked out, by blasting out a layer of marlite about 4 feet in thickness immediately above the plaster rock. When sufficient has been blasted, the overlying "slate" falls down into the hole from which the gypsum has been removed, and the new part exposed can be quarried without removing very much of the strippings. Mr Severance claims that he has to remove only about one third of the stripped rock.

When quarrying the gypsum, three beds are recognized by the quarrymen. The upper bed is the lightest of the three and is about 30 feet thick. The lower beds are of darker color, showing more marked strata of light and dark gypsum. The lowest bed is not always taken out, on account of its poorer quality. The product of this quarry is sold entirely to four firms: Mr T. W. Sheedy, and Bangs & Gaynor of Fayetteville, Gage, Porter & Co., Fulton N. Y., and Craig & Ballanger of Canajoharie N. Y.

The local mills are furnished with gypsum rock in the winter time, and the outsiders during canal navigation. The rock has to be hauled about 1½ miles to the canal. The quarry is operated the year round, and the cost of mining is about 25c to 30c a ton. The teamster hauls five loads a day, averaging four to five tons to the load. Mr Severance's quarry and gypsum deposit occupies about 3 acres. F. F. black powder is used in blasting. The rocks sell, delivered at the canal to the local mills, for 90c a ton. The largest output for any one year was 7000 tons; the average would be about 5000 tons. From four to 12 men are employed at the quarry, depending on the demand for gypsum.

Immediately adjoining Mr Severance's quarry are the quarries of the National wall plaster co. The gypsum deposit in these quarries is the same as that in Mr Severance's bed. The method of quarrying, however, differs slightly. The gypsum is quarried so as to cut under the overhanging rock, which then falls into the place from which the gypsum has been taken. This necessitates moving a greater amount of rock than the method employed by Mr Severance. In these quarries dynamite and Climax blasting powder are used. From 12 to 20 men are employed at the quarries.

The product is hauled 1½ miles to the canal, and to the mill which is located at the canal.

The top layers are used for making calcined plaster. The bottom bed is usually not taken out. In the strippings some hydraulic limestone is found, which is sold to cement manufacturers. The beds owned by the National plaster co. occupy about 5 acres.

At the mill of the National plaster co. the Cummer process is used for calcining the gypsum. This process consists in crushing the gypsum rock in a Blake crusher to about the size of hickory nuts. This material is then taken to a cylinder about 27 feet long by 4 feet in diameter, which revolves over a fire. The smoke is carried through the cylinder so as to utilize all the heat available, and is then taken off by a flue. This cylinder is inclined slightly so that the material runs from one end to the other. The temperature at which the gypsum is calcined, ranges from 600° to 800° F. From the calciner the material is taken to a large cooling bin made of brick. This bin is about 30 feet long by 6 feet wide, by 20 feet high. The heat then permeates the entire mass of rock, calcining the inner portions of the small pieces. The material is drawn from the bottom of the cooler through gates and taken by a worm conveyer to the mills, where it is ground. It is then taken to the storeroom and put in bags for shipment.

The capacity of the mill is 50 tons a day. The annual production is about 50,000 tons a year. This calcined gypsum is shipped, to a considerable extent, to cement manufacturers, and is utilized by the National wall plaster co. for the manufacture of hard finish. For the manufacture of hard finish, it is mixed with certain proportions of sand, clay and a patent retarder.

On the east of the National wall plaster co.'s beds and south of those owned by Mr Severance is located the property of the Adamant wall plaster co. It owns about 19 acres of ground, about 15 of which is underlain by gypsum. This property is not at present worked, but will be opened up this coming year. An old quarry is located at this point, but has not been worked for some years past. At present the Adamant wall plaster co. is using calcined plaster from Oakfield N. Y., and calcining Nova Scotia gypsum. It uses in its wall plaster about one half sand, 8% to 10% of clay and asbestos, and about 40% of calcined gypsum. In the manufacture of hard finish about 7% of ground talc is used as a whitener. The retarder is a trade secret.

The annual production is about 100,000 to 150,000 bags of 120 pounds a year.

The quarries of Mr C. A. Snooks and Mr C. Snooks together occupy about 3 acres. The beds are about the same as those on the adjoining hill. The rock is of a little poorer quality, and they are troubled with water in the quarries. The product is used by local mills entirely.

The gypsum quarries of the Cayuga land plaster co.

These quarries are described in bulletin 11 of the New York state museum, p. 72.

The bed was first opened in 1828, and the original deposit covers an area of about a square mile on the east shore of Cayuga lake, a mile north of the village of Union Springs, and 4 miles south of Cayuga. The output averages about 10,000 tons of plaster annually and 5000 tons of rock gypsum. The entire product is disposed of by Mr Charles E. Lee of Binghamton N. Y. The price per ton of the rock is $1.50; of the plaster, $2.50. The plaster is all of one quality, the poorer specimens of gypsum rock being turned out on the dumps. Only the pure gypsum is used.

The analysis of this plaster is as follows:

Sulfate of lime	80.78
Carbonate of lime	1.76
" magnesium	3
Phosphate of lime	.43
Sand	3.32
Organic matter	.18
Chlorin, potash and clay	10.5
Total	100

This analysis was made by J. A. Barral, perpetual secretary of the Central society of agriculture of France.

About 2 miles north of the quarry which is worked another quarry is found, and at the south about half a mile distant two more. None of these are worked at present.

Marcellus

Near the station a small quarry is worked by Mr Walker. The product is used entirely in the immediate locality. The annual output does not exceed 500 tons.

In grading for a trolley line from Marcellus station to the village an outcrop of plaster rock was exposed in 1900 near the station. The outcrop is about 20 feet thick and extends along the road about 160 feet. The rock shows layers of white fibrous gypsum at intervals ranging from 3 to 12 inches. These layers are from ¼ inch to 1 inch in thickness. The main rock does not seem so solid as the material found at Union Springs and Fayetteville, but should make a fair land plaster. It would probably not make good calcining plaster, on account of the fibrous gypsum. The bed seems to be quite extensive, judging from the fact that it is found at the same horizon just across the valley. The bottom of the bed was not excavated, and it was not found elsewhere on the road, owing to the fact, probably, that most of the rock cuts are above this horizon.

The Wheatland land plaster co., Mumford N. Y.

This company has a mine about 3½ miles from Caledonia, on Allen's creek. This mine is located in a knoll and is entered by a tunnel. The gypsum is in three layers, the best quality being in the middle. The deposit is about 6 feet thick. The mine is timbered throughout. Pillars are left ranging from 15 feet in diameter to 30 x 75 feet, according to the condition of the roof. About 15 men are employed at the works at present. Much of the time the number is increased to 30.

The rock is drilled by a hand power screw drill. The blasting is accomplished by dynamite exploded by a battery. The rock is hauled, on cars holding about 1 ton, by mules to the mill, which is on the opposite side of the creek. The largest pieces of rock are run through a Blake crusher, and from that directly to the mill. The capacity of this crusher and mill is about 40 tons a day. The smaller pieces, up to the size of a man's hand, are taken to a crusher of special design made to order by a firm in Caledonia. This crusher consists of a corrugated cone of iron in which a series of disks rotate. These disks are about 2 inches thick and 1 foot in diameter, having teeth similar to saw teeth. They are fastened to a square shaft and pulverize the rock as fast as a man can shovel it in. This crusher supplies two burstone mills and has a capacity of from 60 to 80 tons a day. In these mills the lower burstone revolves, as this is supposed to give better results. The annual production (according to the Buffalo, Rochester & Pittsburg freight agent) is about 15,000 tons. An interesting feature of this mine is the fact that about 3 acres of old chambers are devoted to the growing of mushrooms. About 80 pounds of mushrooms are gathered each day. The plaster is shipped in bulk in carload lots. Dynamite and black powder are used for the blasts.

About a mile east of this mine at Garbuttsville is located the mine and mill of the Lycoming calcining co. This mill has just been erected, and was being tested at the time of my visit to Garbuttsville. The gypsum is of the same quality as that at Wheatland. The mine is worked in the same manner. The tunnel is about 200 feet long, and a branch tunnel has just been started.

The equipment of the mill consists of a Blake crusher, one continuous calciner with a dust chamber above to save the dust which is used as dental plaster, one cooler, and two vertical emery mills.

The Diamond wall cement co. is to occupy a part of the building for the purpose of manufacturing wall plaster.

The capacity of this mill is 60 tons in 10 hours.

Two 6 foot beds of gypsum are found below the one now worked, with intervals of about 6 feet between.

The Oakfield plaster deposits

At Oakfield, Genesee co., three companies are engaged in mining and calcining gypsum: the English plaster works, the Oakfield plaster manufacturing co. and the Genesee plaster co. Of these the English plaster co. is the largest. About 50 men are employed at the mill, and about the same at the mines. Two mines are operated, each of which is about 40 feet deep. The deposit of gypsum is about 4 feet thick, and screw drills worked by hand are used. Black powder is used for blasting. The hoisting is by steam. A railroad switch runs to one of the mines, and by this is shipped the rock gypsum. The material used in the mill is hauled by teams from the other mine. About 15,000 tons of rock gypsum are shipped annually to plate glass factories at Pittsburg. These factories calcine their own gypsum and use the plaster of paris to embed the plate glass while it is being polished. About 10,000 tons of plaster of paris are produced annually.

The equipment consists of one Blake crusher, one nipper, five kettles and five mills. The nipper resembles an old-fashioned coffee mill, to a certain extent. The upper part, however, consists of a corrugated hopper in which a corrugated cone rotates, crushing the pieces of gypsum to about the size of a hickory nut. The lower part breaks them up to about the size of peas. From the nipper they are taken to the mills, and from the mills to the calciner. Much trouble is experienced at the mines of this company, as well as the other mines in this locality, on account of water in the winter time. Several of the mines must be pumped or abandoned during the winter season.

The gypsum is the whitest that is found in New York state. It is said that about 80 feet below the first bed another bed of gypsum is found about 10 feet thick, but this has not yet been opened.

The Oakfield plaster co. operates three mines, employing about 15 men at the mines and eight at the mill. The equipment of the mill consists of one Blake crusher, two burstone mills, one bolter, and two kettles of 10 tons capacity. The daily capacity is about 60 tons of calcined plaster. The annual product is about 10,000 tons. The material is hoisted from the mines of this company by horse power.

The Genesee plaster co. of Oakfield has just completed a mill which is not yet in operation. It has two mines having steam hoists. The mill equipment consists of three calciners. None of the Oakfield companies have used the Cummer process. The kettle process is used by all.

To the west of Oakfield, gypsum has been found near Indian Falls, which is said to be darker than the material at Oakfield. No commercial use has yet been made of this.

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New York State Museum

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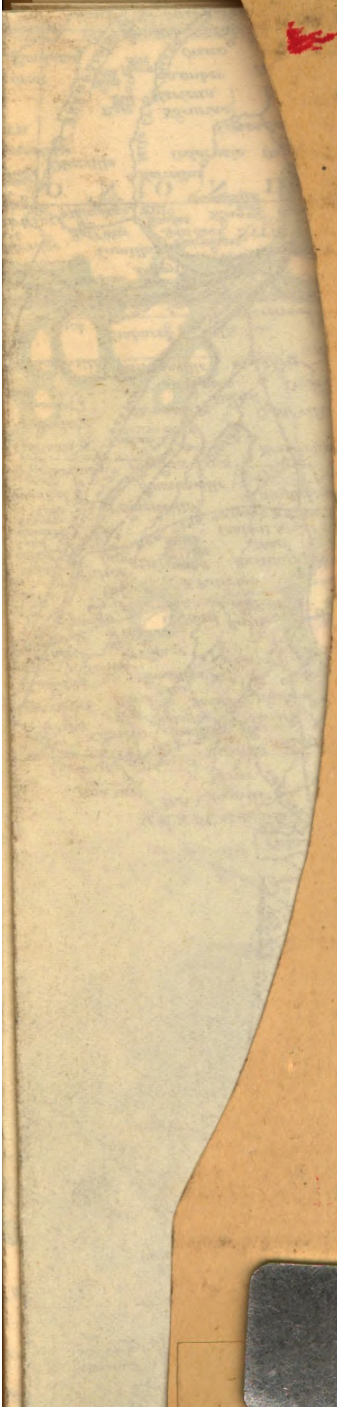

Plate 19.

Map of the shore line and area of Lake Iroquois

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